Shipbuilding
COST & PRODUCTION
Methods

Shipbuilding COST & PRODUCTION *Methods*

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SHIPBUILDING TONNAGE COMPARISONS FOR 1928

COUNTRY	TONS	SCALE GROSS TONS
GREAT BRITAIN AND IRELAND	1,574,000	
GERMANY	405,000	
HOLLAND	347,000	
JAPAN	144,000	
DENMARK	139,000	
UNITED STATES	124,000	
ALL OTHER COUNTRIES	538,000	
TOTAL WORLD TONNAGE	3,271,000	

TONNAGE COMPARISONS OF BRITISH DISTRICTS WITH NEWPORT NEWS

SCOTLAND-R.CLYDE	605,000	
ENGLAND - R. TYNE	321,000	
ENGLAND - R. WEAR	205,000	
ENGLAND - R. TEES	137,000	
ENGLAND - R. MERSEY	115,000	
IRELAND - BELFAST	77,000	
UNITED STATES- ALL	124,000	
NEWPORT NEWS, VA.	40,000	

Introduction

Shipbuilding is one of the oldest industries. It plays a vital part in the security of a nation in a time of war and in the economy of a nation in a time of peace or war. Without ships America could not have participated in the present World War.

In launching this new book on *Shipbuilding Cost and Production Methods* it is worth while to mention the tremendous growth of the industry during the present war. At present there are about a million and a half people employed in the shipbuilding and shiprepairing yards of the United States, and about an equal number employed in the production of materials and equipment used in the building of ships. The industry has expanded about fifteen times in this five-year era.

Another comparison is interesting: back in 1928 the shipyards of the world produced only 2,700,000 gross tons of ships, equivalent to about 4,000,000 deadweight tons: on September 17, 1943, in his message to Congress the President stated that in two months of this year American shipyards delivered 281 large merchant ships totaling 3,200,000 deadweight tons. In other words, the United States is building ships five times faster than was done by the whole world some seventeen years ago.

At the present rate, the shipyards of this country should produce about 19,000,000 deadweight tons in 1943, to which must be added the naval vessels built, approximately equivalent to an additional 19,000,000 tons of merchant ships. In the President's message is this statement:

> "The number of fighting ships and auxiliaries of all kinds completed since May 1940 is 2,380 and 13,000 landing vessels."

Looking at the chart shown here of the output of the world and of the United States in 1928, we see that the United States

built only a fraction of world tonnage that year—124,000 tons (gross), 4 per cent of the total. At the present time it is building by far the greater part of the entire world production. The change is momentous. We are building ourselves sea-legs. We are at last becoming a front-rank maritime nation; and everything pertaining to the better building of ships will certainly continue far beyond this present period to command widespread interest.

The author of *Shipbuilding Cost and Production Methods* is well known in the shipbuilding world. He is a graduate of the United States Naval Academy, and received a Master of Science degree from the Massachusetts Institute of Technology, after which he worked in both government and private shipyards for a long period, and was intimately associated with the factors of cost and production. His achievements and his reputation in the field are secure, and it is believed that this book will be a real help to younger men in acquainting them with these important factors in the great industry of shipbuilding.

H. Gerrish Smith, *President*
Shipbuilders Council of America

New York City
November 18, 1943

Prelude

Twenty-eight years ago (1915) a little book by the present author, also about shipbuilding methods, was published by the Engineering Magazine Company, New York.

The book of 1915 was titled: "Estimating the Cost of Work," but dealt with shipbuilding costs especially, and with planning and production methods in shipbuilding.

At that time I was a young Naval Constructor, on duty at the U. S. Navy Yard, Charleston, S.C., from 1912 to 1914; then transferred to Washington, D.C. for my last year's duty in the Navy before my resignation in June 1915 to enter a manufacturing business at Bridgeport, Conn., where we manufactured military rifles and bayonets for the Allies. There I was first the Production Engineer and then Production Manager until the U.S.A. entered the last World War in the Spring of 1917. Since then my work has been shipbuilding again, in several yards, usually as Production Manager or corresponding positions; or as a Consultant.

In the past twenty-eight years a lot has happened in the shipbuilding business, a lot of improvement in every respect; yet some of these improved methods had their foundation some years ago, even before the First World War. Some basic and fundamental principles were conceived and practiced in many modern ways in several shipyards; and it has been a pleasure to many of us "Old-timers" to see that we had ideas about "pre-fabrication" and "pre-assemblies" and such "modern things" as far back as the year 1906. I cite the Bethlehem Yards at Fore River and the Newport News Yards in Virginia. I could name others in the U.S.A. For example, I might cite the work of the Dickey brothers in California (Union Iron Works), who built that fine battleship, the U.S.S. *Oregon*.

This book is the kind of book that I have enjoyed writing. After 1915 it was forced upon me to do a lot of other technical writings, mostly for technical magazines; usually about the building of ships. Then, for the past several years, especially the past three years, my shipbuilding friends and associates have been urging me, also encouraging me, to get busy and *finish* the job. "After many years," they have told me, "don't stop now." They gave me the "Incentive" (you will find a lot in this book about incentives).

For the past year and a half, and more, it has been my privilege to be in Canada as Consultant for shipbuilding, especially escort vessels. Some of the ideas and data in this book have been put together from the experiences in Canada, a fairly new shipbuilding country; but after only about three years in the business (with the exception of a few yards) they have done well indeed.

In this new book about shipbuilding methods, and the so-called "modern" methods of production applied to the business of shipbuilding, many pages are used from my book published in 1915, which deal with basic principles that do not change, certainly not in the twenty-eight years since its publication. They will not change during the next twenty-eight years either, or hardly the next one hundred years. The original text of the 1915 book has been drawn upon in this present book (with very slight changes in words or phrases, but no change in the thoughts) in Chapters 6 to 13 and Appendices F and G.

The author is indebted to many old and new associates in the shipbuilding profession for many helpful suggestions and ideas during the past thirty years which are incorporated in this book.

WILLIAM B. FERGUSON

Quebec City, Canada
October, 1943

Chapter 1

Peculiarities of Shipbuilding Management

Is shipbuilding management the same as manufacturing management? The answer is No, it is not the same.

However, many basic principles of management hold for all industry. In the broad sense, organization is the same—with Presidents and General Managers, Superintendents and Foremen—with Purchasing Departments, Personnel Departments and all other major departments necessary to industrial concerns. Moreover, the mechanical processes in ship construction are not so very different. Not only in shipbuilding do we find riveting, welding, electrical work, piping, carpenter work, and painting, but in all sorts of building and construction as well.

Then how does shipbuilding management differ from that in housebuilding, in the automobile, sewing machine, steel or candy-bar industries, or any other "repetition" manufacturing?

1) In straight manufacturing, and especially in mass production of articles of identical design, we find a "repetition" of operations and processes, day after day. To produce a million identical articles Operation X17B12 is performed a million times.

In shipbuilding, in normal times, no company is called on to produce a hundred, or even ten, vessels of identical type and design. In lean years you are lucky to get two or three of a kind.

If you take the time to examine this primary difference, you can see that it holds for all ships, but particularly for naval

vessels and others of special design which have not yet been fully "standardized."

2) The second item is one that might never occur to a manufacturer who takes a leap into shipbuilding, sight unseen.

In a factory (say, a machine shop) the machines stand still. The milling machine or the lathe or the drill press do not move. Neither do the operators of these machines move very much. The *materials* which they mill, turn and drill do all the moving, being supplied to the machines according to a definite plan.

But over half of the labor spent on the building of a vessel is, in most yards, out on board the vessel, and not in the shop. In some yards not equipped for making engines, boilers and auxiliaries, the "outside" labor on the vessel may run up to 75% of the total force in the yard.

The point about work done on the vessel is that the *men* move with their tools while the *material* stays in one place. Many men working do "handwork" only, and have to move from space to space.

In this respect the finishing up or so-called Outfitting of a vessel—especially naval craft—is sharply different from regular manufacturing. Observe the results as regards Routing and Dispatching:

In a machine shop materials are routed from machine to machine. Each piece of material is tagged, and the tag sticks with this piece from layout section to lathe group (or section), then to drill group or automatics or to planers or to slotters, or other machines in sequence.

Out on board the vessel, the materials are routed to the proper location in a predetermined sequence, all ready to erect or install. But here the movement of materials stops, and hereafter the gang of workmen does the moving from space to space, changing location as the job progresses. This means that we must plan to route and dispatch the workers. One consequence, of considerable importance in shipyard manage-

ment, is that it becomes advisable, in fact, highly necessary, to distinguish between *shop* work and *ship* work in keeping records of men and hours and labor costs.

There are still other points of difference which should be considered, of which just three will be mentioned here.

3) Limited spaces or compartments in most vessels makes it necessary to plan for fewer men at one time in one space, and for each Trade or Crew to take its proper turn. Not over three Trades can be expected to work in one small working area at the same time. This type of planning is not found in other building work to any extent, except for housebuilding and power-plant construction.

4) In finishing up a vessel, particularly a special type of vessel and, above all, naval craft, piping and electrical work and ventilation systems—as well as other installations—are not the same in each space or compartment. An ocean liner may have some staterooms of almost identical design but, in general, we do not get a chance to "repeat" operations, space after space. They are all different. Vessels generally (except such as coal barges) are radically unlike a house, with its rectangular construction and straight lines. A ship has curved lines for all surfaces next to the water and all outboard surfaces. The shipbuilder has to deal with bevels and crowns and sheers; he must have mold lofters and shipfitters and other specialized craftsmen who do not exist at all in other industries.

5) Lastly, in controlling labor costs and trying to get the best productivity per man or gang, the shipbuilder does not keep costs by "objects" as in manufacturing, but by departments. This will be further examined in Chapter 7.

MAJOR SHIPBUILDING PROBLEMS

To conclude this chapter it might be well to mention two problems, always important, which today the shipbuilding industry is finding even more urgently in need of solution—they

are (1) reduction of manhours and (2) reduction of costs.

Some records of performance in wartime merchant vessel construction have been published. As to the total manhours expended, some of these records are nothing to brag about; and no doubt the shipbuilders will take to heart the remarks of Admiral Emory S. Land, Chairman of the U. S. Maritime Commission, as published in the *New York Times,* May 22, 1943:

"Last month our American shipyards turned out 157 merchant vessels, the greatest thirty-day record of all time. This month, that record is being beaten."

He cited rising production as "convincing proof that both labor and management in our shipyards have not rested content with their record-making achievement of 1942," and said the present rate was an increase of 4,000% over that originally planned in the inception of the Maritime Commission's program in 1938.

Nevertheless, he said at a press conference following his speech, the shipyards "must get more productivity per individual." This was essential, he explained, because of the critical manpower situation. The cost of building ships was "entirely too much," no matter where they were built, but that cost was dropping with increased production, he declared.

It is far beyond the scope of this book to cover more than a few basic features of shipbuilding—just enough to indicate that Production Control is something to be studied and used, in peace or war, for building vessels speedily, economically, and still of best quality. The manpower problem mentioned by Admiral Land in the news item quoted—how to get more output per manhour—is the heart of the matter and has been the

main objective of the author's efforts in shipbuilding for many years.

Cost Control is not costkeeping alone, any more than Material Control is material-keeping (Storekeeping). Yet the keeping of adequate records is the starting point, the keystone of the control structure. The need for Cost Control is indicated by this statement, published in an Associated Press news dispatch, June 24, 1943:

"We've finally learned how to build ships, but the cost is much too high, both in manhours and in money," declared Rear Admiral Howard L. Vickery, vice-chairman of the United States Maritime Commission. "Both must come down," he added, during an inspection tour of shipyards at Los Angeles harbor yesterday.

The problem therefore is: Just how to go about reducing the cost in manhours and money.

When we read the published records of manhours taken to build 10,800-ton cargo vessels (Liberty ships) in different yards, we can readily see the significance of the comments by Admiral Land and Rear Admiral Vickery. In one large yard, the average for twelve vessels was about 390,000 manhours; in a small yard the manhours on a vessel were nearly *four* times as much. In still another yard, the manhour cost was less than 300,000. How can these wide differences be accounted for?

A prime purpose of this book is to point out the step-by-step methods successfully put to use by some shipyards which have resulted in cost reductions of first magnitude.

In fact, if each yard could benefit by the combined experiences of all other yards in this matter, it would mean a great deal to the shortage-of-manpower situation. In order to stress

this idea, suppose we put down a few figures for illustration. They are hypothetical figures as to the total forces engaged on vessels in the United States. (The present number is actually well over a million.) Three sets of figures, (A), (B) and (C), are given, for total workers in all yards for all types of vessels; and also three columns, I, II and III, for relative "productivity per man." *Par* (or 100%) does not mean perfect, but just the present *best* shipyard record.

	I	II	III
Total Workers (at Par)	100%	80%	60%
(A) 1,000,000	1,000,000	1,250,000	1,667,000
(B) 600,000	600,000	750,000	1,000,000
(C) 100,000	100,000	125,000	167,000

Now let us look this over and see what it means in manpower in the shipbuilding industry. For easy figuring, take the round figure of a million workers engaged in all yards. Assume a "productivity per man" of 60% as the average yard record. The table indicates that the work turned out by a million workers at 60% of par could be accomplished by only 600,000 at 100%. Result: 400,000 more employees required at 60% than at 100%.

Here is a "manpower shortage" indeed!—of 400,000 men, due to need for more productivity per man.

The total of 100,000 workers in column (C) is more of a peacetime figure. But manpower is quite important in peacetime as well as in wartime. If we can manage to train 100 men to do the work of 125 untrained men, we save 20% in manhours. It is worth doing.

Chapter 2

Organization of a Shipyard

In every yard, large or small, there are certain "functions"—things which have to be done by somebody. These shipyard "functions" are also required, in principle, in manufacturing or other industrial work, but not perhaps to the same degree. Some features are peculiar to shipyards and their problems.

However, in *any* business, *Organization* (and Personnel) comes first. Hence we should make a special study of this matter, and then consider the further technical aspects of building ships in more detail.

A TYPICAL SHIPYARD ORGANIZATION

A shipyard organization is usually visualized on a chart or diagram. For an example, instead of taking a very big shipyard, with many thousands of employees (some large yards now employ 30,000 each) we will consider a smaller yard of, say, about 3000 employees, which will simplify the organization chart as well as the description of some of the functions. The chart shown in Figure 1(a) would fit a yard of 2000 to 4000 employees, with some minor modifications. On this simple chart, the word "Platers" is used to cover all the steel work, shop or ship, not otherwise indicated; a more complete list of trades appears on Figure 1(b).

We shall confine the following largely to a description of the duties or functions of the Production Control and Personnel Management divisions, though this does not mean the work of other departments may not be of equal or greater importance, from other points of view.

Therefore, we begin with the duties of the Production En-

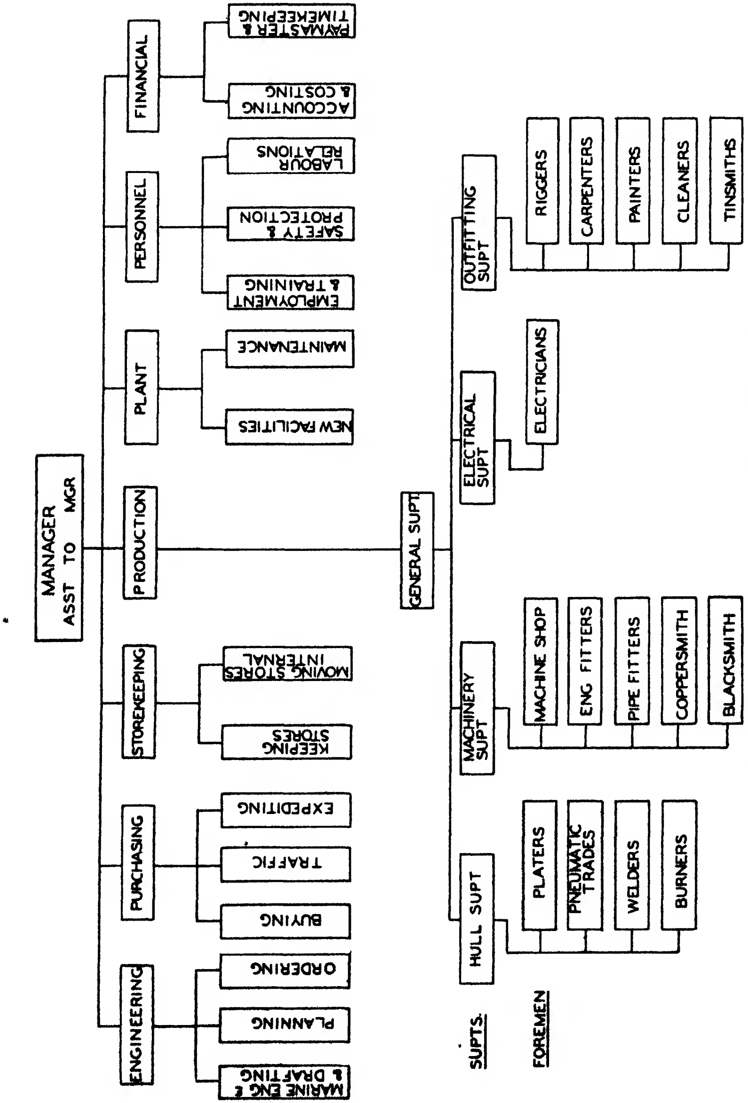


Figure (1a): Shipyard organization chart.

gineer, who usually reports directly to the Production Manager, or Works Manager (or whatever the title may be) who is in charge of production, under the President or the General Manager. See Figure 1(b) for Organization Chart for "Production Manager."

DUTIES OF THE PRODUCTION ENGINEER

The Production Engineer is responsible to the Production Manager for the performance of the production staff duties briefly described under the following headings. The Production Engineer also acts for the Production Manager in the absence of the latter.

Cost Control

Expense and labor budgets by departments
Critical comparisons of actual cost with budgets, by departments
Cost system development

Master Schedules

Master schedules, general planning and allocation of work
Coordination of material control system with the master schedules
Critical comparisons of actual progress with master schedules and expediting work as required to meet delivery dates
Reports for progress payments

Estimating

Cost estimates for all work except ship repair and plant work
General review of ship-repair estimates amounting to $10,000 and upward
Determination of the desirability of work to suit production facilities
Delivery dates for all proposed work
Job orders for all work except for ship repair and plant work

Time-Study Office

For duties of this department see page 13.

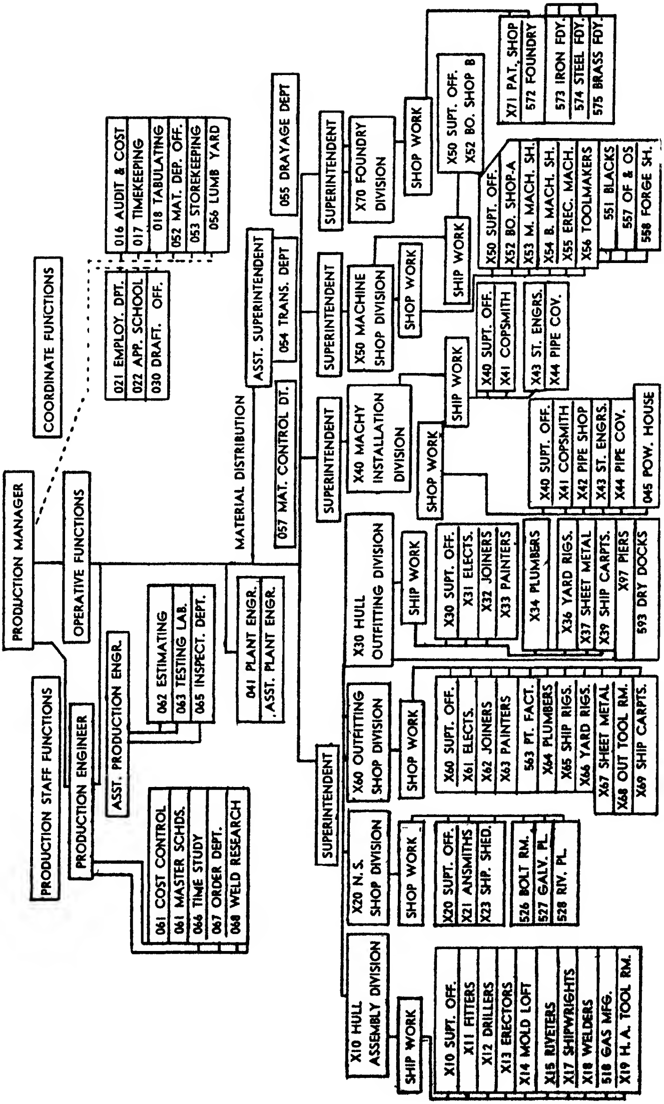


Figure (1b): Chart of production functions, showing ship and shop work separately.

Order Department

For duties of this department see separate heading in this section.

Welding Research Department

Development and extension of welding and cutting to all classes of structural work, and cooperation with the design, sales, and operative departments to this end

Welding and cutting research and tests

Recommendations on mechanical methods and on the design and purchase of equipment and supplies for welding and cutting

Standardization of welding and cutting practice

Supervision of training and certification of welders.

Note: The Assistant Production Engineer will exercise such supervisory duties in the above list as are assigned to him by the Production Engineer.

DUTIES OF THE TIME-STUDY DEPARTMENT

1) Make time studies and collect data on all classes of work
2) Get this data in such shape that it can be used for estimating and for establishing piece-work prices
3) Establish units of measurement for all classes of work
4) Suggest improvements in methods, tools, fixtures, and equipment wherever possible to increase production
5) Promote the cooperation of the workers with the incentive systems
6) Furnish the superintendents, assistant superintendents, or foremen with any data they may require which the department has, or can collect
7) Establish piece-work prices in conjunction with foremen
8) Write all piece-work price tickets
9) Prepare uniform working of piece-work tickets for the respective classes of work to be done
10) All piece-work prices to be set before the work begins

11) Check totals of piece-work prices with labor budgets
12) See that approved piece-work prices are not increased or decreased, except for increase or decrease in work. When prices are increased or decreased, a statement in writing, covering in detail the reasons therefor, must be submitted and agreed upon
13) Furnish any data required by the Production Engineer for estimating purposes
14) It is to be understood that no piece-work price is to be put into effect until approved and signed by foreman of department or some one whom he may designate, and by some one in the Time-Study Department.

DUTIES OF THE ORDER DEPARTMENT

The principal work of this department has its beginning in the receipt of plans from the several drafting offices in which they are made. This work consists of taking from the plans or bills of material all items to be manufactured and issuing production orders for them to the departments to do the work; making out and issuing identification tags to accompany each part through its interdepartmental routing; making from the plans, and issuing, the necessary blueprints to the shops and departments to do the work called for.

This work, and certain other duties carried on by this department, are more particularly described under the following headings:

1) Production-Order Section. It is the duty of this section to write the production orders from the plans or other sources of design authority and to indicate on the orders the interdepartmental routing for each item from its source to destination; to make out the tags to accompany and identify each item; to apply the routing to the material-control record sheets; and to make out the distribution lists for blueprints for the departments doing the work, superintendents' offices

and others concerned. It is provided in the routine of this work that the distribution to departments of copies of the production orders and blueprints, material-control record sheets, and the route of the identification tags shall agree with the routing shown on the production orders. In connection with the duties of this section it may be noted that certain classes of work, such as built-in structural work, do not require detailed routing on the production orders. For this class of work the same care is exercised in making out the distribution lists for blueprints for all concerned as for work going through the manufacturing departments. Certain miscellaneous duties are performed by this department, as it affords a convenient center in which they may be handled: such as catalog of material stores symbols for inventory purposes, catalog of drop forgings and balance-of-stores work for this class of material, summaries of weights placed on board ships and similar weight summaries as needed, multigraph work.

2) The Blueprint Section. This operates all blueprint-room equipment, makes and delivers the blueprints and other reproductions as called for by the print lists and keeps suitable records to verify their distribution. This section also clears back to the files the tracings and other original sheets after the prints have been made.

3) Weight Office. The work of this office consists principally of weighing, or compiling weights from authentic sources, of designated groups of material placed on board ships, and reporting these weights to the Estimating Department.

DUTIES OF THE EMPLOYMENT MANAGER

The Employment Manager is responsible to the management for the supply and training of suitable labor and for the promotion of harmonious industrial relations. This work is organized under several headings, given briefly as follows:

1) *Employment Office*

Correspondence	Transfers
Interviews	Re-ratings and promotions
Placements	Furloughs
Ratings	Terminations

2) *Employment Records*

Service	Earnings
Occupational	Turnover by departments
Attendance	

3) *Employment Service Information*

Addresses	Houses and apartments
References	Miscellaneous service work
Board and lodging	

4) *Training*

Apprentice school	Job training

5) *Industrial Relations*

Employees' representation plan	Plant publications
Safety committees	Other activities

DUTIES OF THE PLANT ENGINEER

The Plant Engineer is responsible to the management for providing suitable buildings and equipment for carrying on the productive work of the plant in an economical and expeditious manner. It is his duty to advise with the various department heads and investigate any requests for new equipment or buildings, changes in locations of present equipment or alterations in the design to increase efficiency, and to design any needed special equipment which cannot be obtained from the usual sources. This work is organized under the following headings:

1) Office Staff
2) Buildings and Structures Section
3) Machinery-Design Section
4) Small-Tools Section
5) Electrical Section

1) The *Office Staff*, in addition to other duties, keeps records by numbers and locations of all numbered machines and other equipment throughout the various departments. This section also takes the monthly readings of all meters measuring electric current, gas, and water purchased, and of such other meters as are installed to record the electric current, gas, water and steam used in various parts of the works.

2) *The Buildings and Structures Section* is in charge of a structural designer who is capable of designing buildings, cranes, crane runways, etc., and of advising the overload load-carrying capacity, if any, of any bridge crane, jib crane, or building structure in the yard. Also, in this section is a building inspector whose duty it is to inspect all buildings, estimate the cost of repairs or proposed changes in the arrangement of buildings or their equipment and to see that repairs and changes are carried out in a satisfactory and workmanlike manner.

3) *The Machinery-Design Section* is in charge of a machinery designer who is capable of designing special equipment and advising as to the overload capacity of existing equipment. This section also has charge of the design of special tools, jigs, and fixtures required for unusual jobs.

4) *The Small-Tools Section* is in charge of a small-tools inspector who has charge of the inventory of small tools, the interdepartmental transfer of small tools, tests, and standardization of small tools. This inspector's duties also include the inspection of all requisitions for small tools, to be sure that only those that are standard will be ordered.

5) *The Electrical Section* is in charge of a designer who is capable of designing, laying out and ordering switchboards, control equipment, and motors, and of determining wire sizes, etc., for power transmission.

Emergency machinery repairs amounting to $50 or less are taken care of by the repair department directly, all charge being made directly against the machine number. For major

three days before the corresponding pay-day. That's the way it should be. Unless the foremen get prompt reports of the labor hours or costs from the Cost Department, then they will have to keep their own records thereof—in self-defense. That is bad, because so expensive, and it is besides a staff job. Foremen are too important to indulge in such functions.

But if this bookkeeping work is done by hand and not by machines, some scheme has to be devised to shorten up that time lag between Payroll and Costing records. It is not very difficult if studied out, but it is often neglected—so that those *responsible* for labor costs do not get reports of their expenditures until the information is "cold" and there is not much they can do about it.

In this business of producing ships, or any other industrial production, there are certain basic principles or *Truths* (some are axioms) that all the debate, discussion and opinions of the opposition can not change. As the Poet says:

"Truth crushed to earth will rise again;
The Eternal years of God are hers:
But error wounded writhes in pain
And dies amidst her worshippers."

If my memory serves me correctly, I think that it was Harrington Emerson who called the turn on this matter of *records* some thirty years ago; and said that all essential records should be

"Adequate, Accurate, Prompt."

That statement is true today and will be true after today, for a hundred years or a thousand years.

Chapter 3

Production Control Methods

Shipbuilding is one of the oldest of industries, and that may partly account for the historic fact that the old-fashioned ways of building ships continued to exist up to about 35 years ago. With the advent of new industries, with new ideas, new methods—new blood—such as automobile and aircraft manufacturing, then shipyards all over the world and particularly in the United States began to take notice of modern methods. The last World War gave considerable impetus to the idea of using modern production methods in shipbuilding.

However, we are still apt to think that this planning and estimating business is not so important as many other things in shipbuilding. Quite recently I listened to a successful and buoyant business man say that there's not much difference between bridgebuilding, housebuilding and shipbuilding. He said, "It's all a matter of a few strong men at the top, men who do things and bear down on their subordinates who do not get results."

Another man in the group, who had learned a bit about shipbuilding in the past three years, disagreed with the statement and said to his friend:

"Tom, that's where you are wrong, and I am here to tell you that I made the same sort of rash statements three years ago. There is such a big difference between shipbuilding and other sorts of building, and I'm going to learn more about it. I'm going to study shipbuilding and take a regular course, for I've discovered that there's a lot I can still learn about shipyard management as distinct from manufacturing management. The mechanical processes may be similar and men can be trained to do all these processes and operations. But the top

men have to know more than that. Shipbuilding is a pretty tough profession, Tom, and make no mistake."

Just then the speaker was interrupted by the general manager of a large company engaged in manufacturing, who said, "Yes, Joe, I agree with you, but I'll add this statement, being myself only recently connected with ships and the building of them. My view is this: Ahead of big, brawny bosses comes *planning*. I mean definite planning in advance for materials and men and everything else."

MANAGEMENT FACTORS

There are about a dozen major elements or "Management Factors" in successful shipbuilding. Some are also called "mechanisms." Manufacturing has similar factors. They have to be considered as a family, each member related to the others very closely, and each more or less dependent on the others.

In this large family of twelve, the senior member is Material Control, when they are considered in the order of effect on progress as regards quality of work, speed of construction, and especially the matter of Costs.

Before defining what is meant by this term Material Control, we should probably mention others in the "Management Factor Family," somewhat in the order of their importance. Bear in mind that these factors concern a yard which is a "going concern" and not one just conceived, for in such a case the yard itself, its layout and facilities, are of the first importance.

Next to Material Control in effect on reducing costs comes Planning and Scheduling. (Arranged in chronological order, this would come first.) The Planning Department handles among other things the problem of labor control—employment and training, based on an estimate of the number of workers required from period to period—and details of daily assignment of men to jobs in each Trade, handled through the foremen. Progress records (an important part of Material Control) are kept by the Progress Section of the Planning Department.

A third member of the family is Costkeeping and Cost Control, taken up in detail in Chapter 7. Cost Control is dependent upon costs kept by organization units for both labor and overhead. The purpose is to have at hand and in simple, understandable form, for the benefit of Manager, Superintendents and Foremen, records of hours (or dollars) spent by each foreman—that is, by each crew or Trade—each week on each vessel, and the totals to date.

Standing in fourth place in the family are Incentive Systems, discussed in Chapter 6.

These are the "big four" in the matter of cost reduction or improvement in Production Control, the basic functions of a production manager who seriously applies production methods to shipbuilding.

Certain yardsticks or records of past performances by other yards are available for all major Trades; and if progress records and performance records are kept, as is customary, these will prove invaluable in controlling costs and labor.

The other members of the Management Factor Family are of somewhat different nature in a going concern. They pertain to technical groups which have already set up methods and procedures, and until they function quite well the four production factors are rather helpless to make any improvements in cost reduction. The most important of these other members include (a) Purchasing; (b) Storekeeping; (c) Marine Engineering and Drafting (No. 1 in value); (d) Plant Engineering; (e) Personnel Management.

The Author's book published in 1915, "Estimating the Cost of Work," described many of the features that still exist in the application of so-called "Production Methods." Five years later the Author wrote six special articles on the same subject—"Production Methods in Shipbuilding,"—in which the methods used at the then largest shipyard in the world, Hog Island, Pa., were briefly described. Some extracts will be given below.

Then, 1924 to 1930, the Author was Production Manager at the famous shipyard in Virginia, on the James River, Newport News Shipbuilding and Dry Dock Co., and wrote for magazines several articles along the same lines. Later on, extracts will be given from some of these Articles, especially on the topic of Material Control.

Later on, in 1941, as Production Manager at a large yard in Los Angeles, the Author had associated with him some very capable executives, and we designed and developed a "Production Control and Cost Control System," which was somewhat similar to the previous developments described—as of 1915, 1920, 1927, 1933.

The remarks above are merely to emphasize the fact that certain fundamentals or principles of planning and shipyard management (Production Control) do not change. It is only in adaptation to new yards, new conditions, new types of vessels, that they vary as time goes on.

That is why "Production Management" is rather a separate and special field in the shipbuilding business—it is universal, it is permanent, regardless of new designs and new types of vessels. The highly technical work such as designing and drafting and making correct and complete bills of material is a profession all by itself. These are jobs that only graduate Naval Architects and Marine Engineers of long practical experience are capable of handling.

However, make no mistake in assuming that a Production Manager or Production Engineer doesn't have to know all about the ships or boats being produced. And the men put on staff work—planning and progress work, Material Control, Cost Control—have to be taught and trained with patience and with care. That is true for every department, yet this training and teaching is often ignored and neglected. . . . It pays to do these things.

Chapter 4

Material Control: The Heart of Planning

Now, let's get back to Material Control, its meaning, its comprehensive scope, and the reasons why it must precede any effective Production Control which can turn red figures into black when fierce competition exists.

The following quotations are from articles published by the Author early in 1920, in "Industrial Management."

"In our previous articles we have dwelt upon the necessity of preparing a master plan or schedule for the building of a ship; then preparing detailed schedules for every piece of material that enters into the ship, so as finally to insure that the various groups or sub-assemblies of material will arrive at the building ways or at the outfitting docks in the proper rotation and without any missing pieces.

PLANNING BY GROUPS

"Enough has been said in previous articles regarding planning by physical groups to make clear that the success of planning in shipbuilding is dependent to a large degree upon the proper classification or grouping of materials or of labor operations. I want to expand on this thought a little further and bring out a distinction between the groups used for material up to the point of erecting the material by groups in the ship, and afterwards the kind of grouping by 'berths' or physical sections of the ship, after the material is erected in the ship.

"All the initial planning and scheduling, beginning with the drawings and continuing through the purchasing of the ma-

terials, fabricating of the materials, and delivery of the materials to the storage yards or ways, and erection of the materials, is by sequence groups or lots of materials. The study of sequence groups should not be a superficial study but should take into account the convenience of checking and handling the material by such groups; and these groups should be considered in the nature of sub-assembly groups in ordinary manufacturing; and the language of scheduling and planning used by the management and by the heads of the departments should be the language of groups and not individual pieces.

"In practice it has been my experience that this lack of proper visualizing of material prepared under groups, is responsible for many of the difficulties of material control. That is, instead of trying to visualize the material situation by main groups, and showing the groups either complete or not complete, an effort is frequently made to round up the missing pieces after erection has started in an incomplete manner, so that there is difficulty in ever catching up with the missing pieces.

"Dwelling a little further on the idea of completeness in the erection of material, I want to emphasize once more the difficulties in management which arise when material is not delivered to the ways by complete groups; and by completeness I mean every single piece in the group on hand before the assembly or erection of that group starts.

"If you will take the trouble to find out the real detailed facts on the average ship being built, and start down at the ship with a view to obtaining an accurate record of the number of pieces of material which are missing in each section of the ship, you will, I am certain, be surprised at the amount of work which is being held up by the lack of a few pieces of material. The cause of this condition is, of course, directly traceable to erecting parts of sequence groups in the hope that the remaining pieces which are missing will be coming along before they are actually needed.

"The plan which I advocate is starting at the other end and not erecting *parts* of sequence groups until *all* the pieces are supplied. The missing pieces can be expedited much more effectively before erection starts than they can afterwards. Under a proper material control system there should be no need for expediters or chasers after erection starts.

GENERAL PRINCIPLES OF ORGANIZATION AND PLANNING

"The new attitude of mind toward modern methods is well expressed in the following advertisement, recently clipped from a newspaper, on a large and successful construction company, which we will call the A.B.C. Company:

> Hit or miss methods offer no competition to rising prices. Saving and careful planning go together. Every pound of steel, every yard of concrete that A.B.C. puts into place, every labor group added to a job, or withdrawn, moves according to long time prearrangement.

"Is there a shipyard today that can boast of such a material control system? There may be two or three, but as a rule there is no general belief or conviction on the part of the president and the general manager that the shipyard ought to have a real material control system. The idea is condemned in advance of investigation and study. Yet many of us know from experience and can show by results under such a system that material control is the very heart of economic shipbuilding or manufacturing.

"At the time we started at Hog Island to use improved methods of handling material and tried to standardize the sequence of erection, a great deal of opposition was met, all along the line. This is to be expected with any improvement, particularly if inaugurated by a staff department or by an outside consultant.

"Foremen's meetings were held, night after night, and meth-

ods of building ships, as well as all troubles with materials, tools, etc., were discussed. Gradually those who at first were most violently opposed became the warmest supporters of the innovations.

"At the suggestion of one of the superintendents who has assisted me from the first, a one-page 'primer' or simple statement of what we were driving at was published, which seemed to be well received all down the line. It read as follows:

FUNDAMENTAL PRINCIPLES OF PRODUCTION IN SHIPBUILDING

(1) Deliver and erect all materials, both Hull and Machinery, in a standard or predetermined sequence by groups or loads for each ship, allowing no variations as to the items in a group, unless necessitated by a change in design.

(2) Predetermine the number of workmen of each trade to be assigned to work on a hull week by week, based on meeting our *bogeys* of launching and delivery at minimum cost.

(3) Predetermine the assignments of men *several days in advance,* knowing from experience and from study how much work each tradesman can do every day. Set a date of starting and completing the various elements or jobs throughout the ship, and hold a particular foreman responsible for meeting each date of schedule.

(4) Ensure by such planning that each trade shall come on to a 'berth' or section of work in proper rotation or sequence, and ensure (in advance) that no workman or gang is put on a job until it is ready for him and be sure he has plenty of continuous work ahead, to permit straight piece work where applicable.

(5) Each foreman should be taught to look ahead several days and to know what each man under him is to do tomorrow and the next day and to see that material and facilities are provided in ample time. Foresight or planning will ensure a *chance* for workmen to 'produce.' Then keep records of individual performances, day by day, so as to retain the most efficient, as time goes on.

(6) Hold foremen absolutely *responsible* for their costs, and keep them fully posted as to their costs in comparison with similar foremen on other ships. A foreman who is only 50 per cent efficient is a very expensive foreman to keep.

(7) Low labor costs and good workmanship mean 'Speed of Production' with a given force. This is self-evident. 'Haste' is not 'Speed.' Have supervisors do the 'head work' first, and the foot work next. That is, do not rush men on the job until it is definitely determined exactly what they are to do, and about how long it should take them to do it.

(8) Do not let foremen be afraid to let work 'pile up' ahead of a gang. That is *essential* for efficient performance in shipbuilding as in manufacturing; one day's work ahead at least, and preferably several days' work ahead, to provide continuity of work."

—Official U. S. Navy Photograph.

Aircraft Carrier, U. S. S. Enterprise, built at Newport News, Va.

At Newport News, Va., in that old shipyard on the James River, established back in 1886 by Collis P. Huntington, my nine years' work—seven years as Production Manager—was perhaps my most interesting and valuable experience with modern methods of building ships.

In that big shipyard *quality* comes first. Good ships have been built there for over fifty years, *always* good ships. All kinds of good ships and vessels—from battleships and cruisers, ocean liners and yachts, down to tugboats and barges.

Therefore it seems appropriate to give some quotations dealing with methods in use at Newport News Shipbuilding and Dry Dock Company, a record from about 1923 up to 1933. The first quotation is from the "Shipyard Bulletin" in 1933, three years after the Author's departure.

MATERIAL CONTROL SYSTEM

"Although this subject is very familiar to heads of departments and staff men through daily use and to the men who are attending the study course of lectures now in progress, the following article has been prepared to set forth, in non-technical language, the functioning of this important system.

"It is fairly easy to understand how the flow of material is controlled in a plant which specializes in mass production such as the automotive industry, but when one turns to shipbuilding, he is confounded as to how a vessel can be fabricated without a hitch as to the time of launching and delivery. In fact ship owners have expressed their admiration openly at the precision with which our schedules are met.

"Because of the difficulty of applying the principles in use in many other industrial organizations, shipbuilding has of necessity been forced to devise some adequate system of coordinating its factors. Much thinking along this line has resulted in what is known as our Material Control System. After several years of shipbuilding by this system we are convinced that we can build better ships more economically and in less time than was possible under the old method.

"On October 3, 1923, President H. L. Ferguson issued a memorandum to the Superintendents, Chief Engineer, Material Agent, and the head of the Order Department requesting them to appoint representatives to form a Committee, with W. B. Ferguson as chairman, to work out a material control that would, as nearly as possible, suit all of the departments mentioned. The first meeting was held on October 10, 1923. This committee did such a thorough job of formulating a workable

Material Control System that it was perpetuated with the executive authority to supervise the operation of the system. Meetings are held every two weeks to determine and enforce the steps necessary in maintaining schedules. The importance of this committee to the economical construction of ships and their delivery within the contract time cannot be minimized when one realizes the obstacles which had to be overcome in coordinating the departments of this Yard.

"Mr. W. B. Ferguson's own definition of material control follows: 'Material Control is a term which is used more or less commonly, and is well known in industry. It is not the problem of purchasing material, nor the problem of storing, issuing, handling, or transporting material—these are physical essentials that demand executive action—but Material Control is the scheme or procedure for coordinating all these functions, and is more the detailed plans and methods agreed upon by some set of individuals, for controlling the material "flow" in the manufacturing or building of a product. So, that, in talking about Material Control, I simply refer to the mechanism by which we arrive at a set scheme for each and every department to function by in the big job of getting material on the job before the mechanic starts work. In all this work of controlling material, I just want to emphasize the fact that whatever is done is for one purpose only, that is, MATERIAL BEING ON THE JOB WHEN THE MEN START WORK.' "

* * *

"The logical unit for control purposes is the material group, which is composed of the items that would be handed to a journeyman or a group of men just as if they were subcontractors in charge of erection and who were interested in installing that group completely without interruption or delay before beginning on another unit. A general description of a group is not definite enough to control the flow of the groups to the job for erection. It must be known in detail what makes up the group, and it is essential that every piece of material

in it be listed. Three group lists are made up in the Drawing Rooms after the drawings have been completed and before they are issued to the Yard. This list gives not only a brief description of every item of material making up the group, but also the number of parts, the drawing and item number, the source of material, i.e., the requisition number or stock reservation, and the routing of list of Yard departments which the material must pass before it is ready for erection.

"There are many operations, materials making up these groups must go through, before they are ready for erection, and, unless these operations are properly controlled, the group would not arrive at the point of erection in accordance with the date set. The Material Control System does not attempt to regulate every operation on each piece of material, but it does set up limiting dates all materials in any group should be completed in the various divisions of the Yard. This information is listed similarly to the Group Index. The dates listed cover the work involved from drawings to erection."

* * *

"Some of the accomplishments of the Material Control System may be set forth as follows: It necessitates the members of the supervisory force to plan their work thoroughly; it enables the management and all supervisors to visualize conditions which will exist from three to six months in the future; it has reduced the time required to build a ship fifteen per cent; it has reduced direct labor costs twelve per cent; it has improved the quality of workmanship; it has practically done away with the old way out, 'Passing the buck.'

"The first hulls built at this Yard on which Material Control follow-up methods were used were Hull 276, *George Washington,* and Hull 277, *Robert E. Lee.*"

Perhaps the article published by W. T. Dimm in the U. S. Government periodical "The Merchant Marine" in 1931 will further clarify the developments at Newport News. The title

of the article was: "Handling and Routing of Material in Shipyards and their influence in Reduction of Cost."

Only a few paragraphs will be quoted:

"In a shipyard built without due consideration being given to this important question, any improvement in material handling must be built up around the storerooms or storage spaces, lay-off spaces, shops, shipways, dry docks and piers as they exist and, while conditions may be far from ideal, vast improvements can be made and surprising results obtained. There can be no better way of illustrating this perhaps than by describing what was done and what has been accomplished along this line at the works of the Newport News Shipbuilding and Dry Dock Company. The present material handling system was developed and installed in this plant in 1927 under the direction of Mr. W. B. Ferguson, then production manager.

OLD SYSTEM

"Prior to the installation of the present system a mechanic, when needing a piece of material, would secure an order from his quarterman, the order being written according to the mechanic's description. Upon presentation of this order by the mechanic, or anyone, the storeroom would deliver the material. If the wrong material was delivered or if material was used for purposes for which it was not intended, or was lost, it was reordered. Another fault of this system was that material, often in excess amounts, was ordered out far in advance of the actual date required, often to be lost or damaged.

PRESENT SYSTEM

"All erection work on ships is broken down into *jobs* of such size and location that the material going into them may be installed most efficiently and with the least interference with adjacent work. The material for such a job is known as a group. The storerooms segregate as far as possible all material both

shop made and requisitioned into these groups, which are ordered out by groups on stores orders written by authorized departmental men. Where miscellaneous items or material not covered by the groups are required, the same order form is used. Every effort is made to anticipate the need of material and to order it out in advance of requirements. From two to eight hours, depending on the nature of the material, are the minimum requirements.

"At the fitting-out piers and the shipways are material houses in charge of material men where all stores orders originating in that vicinity are deposited and where the orders are recorded and the material checked when delivered. Located at these houses and at all major stops throughout the yard are mailboxes for depositing stores orders from which they are collected hourly by a messenger on a bicycle who separates and delivers them to the various storerooms from which the material is sent out by route truck.

REDUCTION IN COST

"As the material handling system is only one of several new systems which have been introduced in this plant, it is difficult to assign accurate values to savings directly due to this system. However, there are certain definite items that can be segregated. From 1927 to the present date a 32 per cent reduction in the number of men in the Transportation and Drayage Departments has been made notwithstanding an extension of the scope of these departments which includes the building and repair of roads and yard cleaning. This is in addition to the prompt and better service that has been rendered the yard forces, and the saving of their time, which is partly reflected in the 15 per cent reduction in the time required to build a ship. This saving of men's time is especially noticeable in the procuring of material. Recent checks on the orders received in a day showed that about half of them were being presented

through the regular channels which means that between 500 and 600 orders are handled daily through the mail and by route trucks, while the men requiring this material remain at work. Assuming that a man going for his own material takes from half to three quarters of an hour, it is a simple matter to show that this represents a saving of about 100,000 man-hours per year of, you might say, a skilled mechanic's time for, as we well know, it is usually the mechanic who goes to select his material rather than his helper, except when they both go, which is often true."

—Official U. S. Navy Photograph.

Cruiser built at Camden, N.J., New York Shipbuilding Corporation

So many shipyards now have good planning systems, all different, that it would be difficult to describe these differences and even more difficult to pick out the best planning systems for the various types of yards.

However, it does seem proper to give credit to the Chief Planning Engineer of the Ingalls Shipbuilding Corporation (R. H. Macy) for his succinct remarks, and readable article in the June 1943 issue of "Marine Engineering and Shipping Review" on this and other subjects. Here are a few paragraphs:

"Remarkable progress has been made in developing a schedule which permits the orderly inception and completion of all systems aboard ship in such a way that there is a minimum of interference between the crafts involved, and a balance of manpower is maintained.

"For instance, the electricians are not required to go onto a ship and wait for the electrical machinists to get out of their way and give them elbow room, or vice versa. By planning the job in advance, all electrical equipment, such as motors, controllers and the like, are in place before the electricians ever go aboard to install the lines and cables. Hence, no one has to wait on someone else to get out of his way. One craft or the other has right of way at a certain time.

"Then there was the problem of getting equipment to the yard on schedule. Failure of a pump to arrive on time might cause a devastating delay in the schedule, holding up the pipefitters, who in turn might hold up some other crew. This problem has been solved by using 'dummies,' the system working somewhat as follows:

"When it is apparent that a pump (for example) will not arrive at its scheduled time, whatever may be the reason, a dummy pump is rigged up. It may be nothing more than a set of flanges on a base plate, but it is made to exact dimensions, those parts being in exactly the same relation with each other as they would on the piece the unit represents. Hence, when the time comes for the pipefitters to hook up the pump, the dummy is installed instead and connected to the piping system at all openings. Thus the job goes on without interruption. When the real pump finally arrives it is a minor job to pull out the dummy and install the real pump.

"By developing this system even further, it is believed that it will be possible to install all machinery, even high-pressure steam units on the C-3 type ships, in six weeks, whereas machinery delays previously have held up the operation for many weeks.

"Another problem which is gradually being overcome in construction planning at this yard is that concerning the great concentration of manpower aboard a vessel during the last three weeks of construction; that is, finishing up the many loose ends. Studies are being made to distribute this load still further. It is recognized that this is one important phase of the work wherein man-hours can be materially conserved through improved methods.

"A chart system is used for planning and recording day-by-day progress. For each ship under construction, charts are prepared indicating the schedule for performance of each component of the ship, showing also the actual progress attained from week to week. When consolidated, these give a ready picture of the progress of the vessel as a whole, and make it possible for the expediting department to have the material on hand on time for each installation in the ship according to schedule.

"Another chart gives the complete cycle of operations, with data as to starting and completion dates, with percentage of completion which must be attained at any specific time. Each week this chart is marked up to indicate the actual 'per cent complete' so the superintendent can see at a glance if any department is ahead or behind schedule and to what extent."

While at Newport News, Va., as Production Manager, it was arranged by the President that the Author take a trip to foreign shipyards, accompanied by the Hull Superintendent, E. F. Heard, in the spring of 1929. We visited many yards in Great Britain, Holland and Germany. We learned a lot, the record of which can be found in the Author's seven-page article, "Economic Phases of Foreign Shipyard Practices," published in "Marine Engineering and Shipping Age" in 1930.

However, since this book is mainly about "Modern Shipbuilding Planning and Production Methods," the extracts below must be presented.

"The small amount of welding which was being done in the British yards was very noticeable. In Germany, however, the amount of welding, mostly electric welding, was much greater; but on merchant work not as great as in some American yards."

* * *

"At most of the British yards, they seemed to erect material on the stocks as fast as possible, away ahead of the riveting, a practice which must cause unfavorable riveting conditions. The absence of material grouping and detailed planning for erection in proper sequence, according to the best American practice, is largely responsible for the British building time for large vessels being excelled by American yards, anywhere from 10 to 25 per cent.

"In only two of the eight British yards visited did I see any evidences of detail planning and material control similar to the best American practices. The Dutch yard, however, was quite modern in this respect; and in the German yards there were evidences of great attention being paid to these things. In one yard in England, they had a planning system in their small joiner shop, which was quite effective. Aside from greater labor economy, the time gained by looking ahead, planning for labor and material, and controlling material by groups in sequence is of the greatest consequence, not only to the contractor but to the purchaser. A large passenger ship which takes 20 months to build in the old non-methodical way can be built in 16 months by utilizing these modern methods or tools of management. This was proved in the building of the *Virginia* and *Pennsylvania* at Newport News; 17 months and 15¼ months respectively being required as compared to British shipyard records of 19 to 22 months for ships of corresponding type and size."

Chapter 5

Material Handling Methods

PLANNING AND DISPATCHING

There are certain fundamental concepts of production which it may be well to mention as a preamble.

(1) Material must be controlled completely from purchase to erection under a direct or indirect central control.

(2) Pre-fabrication is the obvious key to a successful program, but the secret of developing all the latest advantages of prefabrication lies in material being released in *complete* job groups, with a bank of material ahead.

(3) Material comes in at a definite speed and the labor must be keyed to this speed. In other words, it is not a bank of work in sight which determines size of labor crews, but the speed at which material is arriving.

Three functions of planning are detailed in the following:

(1) Material Records and Procedures
(2) Erection and Installation Records
(3) Other Progress Records

(1) MATERIAL RECORDS AND PROCEDURES

(a) Specifications. Material requirements are broken down into job groups by the Drafting Office, which prepares Bills of Material from the drawings and specifications. This B/M form gives drawing number, quantities, sizes, and description of material required, together with any special mark or fitting number. This form also is designed for detail check-off of items, arrived in stores. The material group number and requisition numbers are added later.

(b) Delivery Required. This step is the keynote of the material side of planning. Material is divided into 13 classes, corresponding closely to specific trades; these classes are subdivided into *material groups* which are in reality complete jobs, listed in a desired sequence of installation. These material groups are tied up with Bills of Material, and last allowable delivery date is allocated to each group for each boat on the program. These dates start 4 weeks before acceptance of new hull and extend to 8 weeks before delivery. For convenience only seven material delivery dates are established. A complete set of these lists is given to Ordering, Purchasing and Expediting Departments, with individual copies to interested foremen.

(c) Ordering. Bills of Material are stamped with their Material Group number and turned over to the Ordering Department, which consolidates the B/M's into a convenient form for the Purchasing Department, indicating for how many boats, B/M's affected, and the required delivery dates; the requisition number is placed on the original B/M at this time. The Ordering Department translates engineering items and shipbuilding idioms (especially those of British origin) into the commonly-used trade terms, specifying definite catalogue numbers either as requirement or as a guide for purchase, stating which is the case. Any changes in this requisition, when rigid specifications cover the material, must emanate from the Engineering Department. When the final Purchase Order is made up it passes through the Ordering Department for checking against the requisition, and the order number is placed on the Ordering Department records.

(d) Expediting. From the time the order is placed till the time the material leaves the vendor, the Expediter maintains contact with the supplier. There are seven dates of delivery for each boat and these material groups are classified by

dates for all boats, i.e., November 20th may be the last date for material to arrive for one boat, the first for another, and the fourth for yet another. A card is prepared for each material group, giving the material group and boat numbers, description, date, B/M number and requisition and purchase order numbers, this information coming from the Ordering Department. When the order is placed the desired delivery dates are specified, and it is up to the Expediter to meet those dates; as the material arrives it is checked off by material groups on the various material lists.

When the due date arrives all outstanding cards are withdrawn, date noted, and turned over to the expediter for immediate action; his efforts and promised delivery are noted by him and returned to the individual trade planners affected, who readjust their program if necessary. The card is replaced on file with a red tab, indicating that it is an outstanding item.

(e) Material Handling. This covers the handling of the material from the time it leaves vendor till it is stored, and involves the Purchasing Department, Traffic Man, Planning Department, Outside Planner, and the Stores. The Traffic Man is notified by the vendor of the shipment, by car number and order number. He immediately notifies the Planning Department, Expediter and Stores as to expected date of arrival. The Outside Planner checks the order with his material group listing, and knows exactly the degree of urgency. He then informs the Traffic Man how to handle the material. (a) Dead Storage; (b) Live Storage; (c) Shops; (d) Ship; and, if Yard Storage, he indicates the rack number.

The Stores take charge after the car or track is spotted in the exact location indicated by the Outside Planner. Without benefit of Bill of Lading or copy of Order, the Stores material checker makes a "List of Goods Received." This is immediately checked against Bill of Lading and Order and reported to Ex-

pediting and Ordering Departments on a "Material Receiving Report."

The Material Receiving Report is checked by the Ordering Department against their original requisition, which gives the original B/M number. This material is then checked off item by item, boat by boat, on the B/M form, and the information is immediately thereafter transferred to Planning Department records.

(f) Material Records. There are four interested groups recording material—(a) Expediting, (b) Ordering, (c) Planning, (d) Stores.

The Expediter's records are only alive while the order is outstanding—immediately an order is completely filled, his interest ceases.

The Ordering Department transposes information from Engineering to trade items in the ordering; in the recording the steps are reversed. It is here in the Ordering Department that all the various identification numbers are tied together and information passed on—their recording ceases when material is all on hand, but their records remain "alive" for reference purposes.

The Stores Department is concerned with the material from the time it is ordered till the time it leaves the department. Their records are then the most detailed of all, being a continual inventory of material on hand and expected. Their system is maintained by items, and they record quantity ordered, order and requisition number, quantity received and quantities issued.

The Planning Department recording system is not maintained in the detail breakdown of the Stores Department, but their records cover the complete picture from "What is required" to "What is installed," and can be more truly called "Progress Recording."

(g) Issue of Material—Shop Fabrication. (Concerning issue for installation on boat, see Erection Control, following.) An order for shop fabrication is issued by the Ordering Department at the same time that raw material is ordered for the job. A copy of the Shop Order goes to the Outside Planner together with a Shop Bill of Material. The required material may be coming from stock, in which case the Outside Planner places a requisition in the Stores and arranges the delivery of material to the shop foreman's desired location. In the event of material being ordered specially for some specific shop fabrication, then the normal follow-up will proceed, with the material arrival notification returning to Outside Planner, who released the material to shops.

(2) ERECTION AND INSTALLATION RECORDS

In order to utilize labor facilities to capacity it is necessary to release material in a controlled manner to avoid trade interferences.

There are nine main "crews" or trades working directly on the boat and, due to the confined working spaces, the difficulty of trade interference always exists. The first step is definitely to establish, with due allowance for changes in design, the exact location of equipment to be installed, and to transfer this information onto the boat proper in the form of a painted mark-up, which can be deviated from at no time without written authority from Planning and Drawing Office.

Each run should first of all be laid out in chalk. Then markers-off from each trade can go over the line before painting in permanent marks. This mark-up should then be checked over with the owner's representative or inspector, who can make any decisions at that time.

With locations definitely established to avoid physical interference, it then becomes a problem of trade interference. This is a problem that will never be completely solved, but it can

be held to an absolute minimum by intelligent planning and active cooperation.

Each compartment has a certain number of trades which must enter it at different times before it is completed; these can be established and then, by free discussion between foremen concerned and the Planning Department, the order of work established. This order of work is not a rigid program, but one which is governed by material considerations. Its greatest value lies in the fact that it permits a quick and simple method of carrying out a program to completion, as at all times any individual in the organization can tell what is preventing the completion of a compartment, and the necessary corrective steps can be taken.

With the exception of piping and electrical work, material will be released by "compartment lots." These two trades, however, will be delivered material in job groups and will be assigned time intervals to complete their work in a compartment. As each compartment will be affected by a number of lines or runs, it is a simple matter to have pipe or electrical gangs working on separate runs, follow each other through compartments, and in this way to clean up each trade completely in a compartment without delaying subsequent entry of other trades.

It will be the responsibility of the Boat Coordinator and Outside Planner to supply all required material to the foreman in the prearranged sequence and to release the "Go Ahead" on work in compartments. Work memos will be issued as usual by the Individual Trade Planners when material is on hand, but the final O.K. is in the hands of the Coordinator, who will at all times be posted as to the disposition of crews.

Material will be released from the Stores through the Coordinator, who will have material requisitions made up ahead of requirements, and will place these on the Stores for withdrawal, and designate their destination for transit purposes.

A simple card system will inform the foremen of the status of their different jobs. Each card will show the compartment number and name, and the trades listed in their order of entry, with a space for date of completion and for the foreman's signature. A card rack for each trade will be controlled by the Coordinator; as soon as material is on hand the cards will go in the rack of the first trade on that list. This is the foreman's O.K. to proceed; when his work is completed, the card is returned to the Coordinator, duly signed and dated. The card then goes to the No. 2 trade rack. As is obvious, there will be a number of cards in any one trade rack; but this does not mean that *all* these cards should be withdrawn, as it is essential for assuring continuous 100 per cent productivity per man that a foreman hold a few jobs in reserve.

(3) OTHER PROGRESS RECORDS

With a definite program in view, complete records are essential to reveal the *factual* condition of the boat, and to indicate whether the timetable is being met or whether speedups are required.

The actual recording can best be done by trades, as different material requires different methods of analysis.

Steel: Three stages of the steel program are to be measured:

(a) Material on hand
(b) Material fabricated
(c) Material erected

The easiest method of measuring progress in all cases is by weight—each piece of steel going on the boat will be marked and its corresponding weight noted—hence, when a piece passes through any of the three stages, all that needs to be noted is the mark number.

Another definite indication of steel progress is the recording of the final fastening step, either riveting or welding. The num-

ber of rivets driven, and the pounds of welding rod deposited will be recorded daily and plotted against a schedule.

Piping: Records of length of pipe erected and number of fittings installed by jobs, and, in conjunction with this, a record of fabricated pipe, will be maintained by lineal feet.

Electrical: Lineal feet of tray, lineal feet of wire, and number of fittings will be recorded pretty much as in piping progress.

Sheet Metal: By weight of material installed.

Machinery Fitting: Four steps to each piece of machinery—landed, lined up, seat-drilled, and bolted up. Each piece of machinery can be weighted as to relative importance, i.e., Main Engines may be 10 per cent of the Machinery Installation, so that by the percentage position of each piece of machinery its percentage relationship to the job as a whole can be evaluated.

Hull Fitting: Will be much the same as Machinery Fitting, plus a certain amount of visual evaluation.

Armament: Same as Hull Fitting.

Painting: Gallons of Paint used is the simplest record, but square feet is the best.

Woodwork: Visual inspection.

Furnishing: Visual inspection.

To finish an overall picture of progress, each trade's percentage of the whole will be listed, together with estimated total labor hours required; then, as weekly progress is reported, the individual trade progress will be converted into a percentage of progress relative to the complete boat, and by totalling up the labor hours involved an index of crew efficiency is established. This figure should improve progressively and, with an improvement trend plotted, it serves as a valuable guide for labor requirements by trades, taking into account as it does the crew efficiency factor.

Chapter 6

Incentives and Rewards

What makes for interest and enthusiasm in sports? Suppose that no scores were kept and that no records of performances were published, then what would we do for interest?

Even the listening audience becomes interested when someone like the Flying Fireman from Sweden, Gundar Haegg, beats several world's records for speed in long-distance races. Think of running two miles in twelve seconds less than *nine* minutes!

Man O'War, Count Fleet and Whirlaway have made records for speed that thrill all horse-lovers. Baseball fans follow the score intently and keep detailed play-by-play records.

In golf, another sort of game entirely, we find a sport more closely "allied" to shipbuilding, because we shipbuilders used to think we were *good* when we shot an 82, until we read of champions shooting 67 on a Par 71 course. Again, records and the incentives that urge us to beat records supply the essential drive for improvement.

Another kind of comparison is also worth making as between sports and shipbuilding:

Athletes are trained. Even those with native ability and unusual stamina and prowess go through the most careful and scientific training. They have trainers and coaches who correspond to the trainers and advisers in industry; and, in fact, until recently the athletes and best sportsmen (including horses) have taken their training much more seriously than we shipbuilders.

In the Armed Forces, training and discipline are the order of the day; and pre-planning for the campaign and the battles

comes first. The art of war is a profession taking years of preparation, study and practice. Awards are given for meritorious work. In such matters, shipbuilding is a similar profession.

WAGE INCENTIVES

Wage incentives are the topic of this section. There are about twenty-five separate but related types of wage incentive plans, all developed over a period of years for manufacturing industries.

In shipbuilding the piece-work system is the most used (or a variation of piece work); it is simple for a worker to understand and easy for the Cost Department to figure out the individual earnings. Yet the straight piece-work system is not applicable to many unstandardized operations, and we have to resort to other methods in many cases. In Appendix C, some other methods will be set forth. (See pages 166-171.)

There are other incentives besides financial; hope of advancement, the sense of security in one's job, the feeling for the people who run your plant and pride in the work of the outfit which pays your wages or salary. Also, there are many forms of reward for the executives, from president down to foremen and gang bosses.

In any case, the incentives must be provided for workers, if the shipyard expects to succeed in any sort of competition, whether for speed or profits. It is true that there are nowadays a great many plants—shipbuilding and otherwise—which get good production without financial incentives. But in shipbuilding the reward element, the incentive system, is still of greatest value and effect. Ask any yard manager who has tried both.

Let us quote a letter on this topic, signed by Mr. Nathan I. Bijur and published June 18, 1943 in the *New York Sun:*

"Although the increased rate of production of our ships and war materials has been tremendous, it is evident that still

larger shipments would be of immeasurable advantage in hastening the end of the war. This would have been and still would be possible if our available labor produced at a more rapid speed. In peacetimes labor unions provide a speed limit at approximately the speed of the slowest worker. In war-times, limiting of speed of production is a serious menace to a successful prosecution of a war.

"Months ago Captain Eddie Rickenbacker called attention to the advantage that would result from the introduction of incentive wages. Some months later a test was made with incentive wage payments in four plants of the Aluminum Company of America, and the result showed an increased production of 20 per cent without the use of additional labor.

"A few weeks ago a Regional Labor Board announced in a decision that 'As a general policy we will approve those plans which result in a lower unit cost, since the resulting increased production is to be desired in these times.' But they limited this decision by not permitting wage incentive payments unless the cost was lower, not being satisfied if the cost was no higher than under the present system. In the same decision the board said quite frankly that incentive wages would result in a 17 to 20 per cent increase in production.

"It is incomprehensible that incentive wage payments, for the duration, are not immediately adopted wherever possible, for, if without extra cost and without employing additional labor, we can increase our output by 20 per cent, it would mean that we could produce 40 per cent more ships, war planes and war materials."

PIECE-WORK PRICES

This chapter will have to do with piece-work prices merely as comparative estimating data. A good piece worker for many years has earned from 20 to 60 per cent more per hour than a day worker (dependent upon the trade and operation), and

the output per day of a good piece worker is usually about double that of a day worker. It varies somewhat, of course, but where conditions are favorable, especially as to material being on hand and ready for the workers, the men with incentives (piece workers) turn out much more than the men without such incentives (day workers). Never less than a third more, sometimes more than twice as much.

For example, riveters: A piece-work riveting gang, for many years, has handled about double the number of rivets per hour that a day-work gang does; and the prices enable the good piece-work gangs to earn 50 to 60 per cent more a day than the day-work gangs. Riveting is a hard physical job; and riveters don't last as long as most of the other trades. They correspond in this to baseball players, who are usually "old men" after they pass 35.

Other trades, not taking so much out of the men physically, do not expect or require incentives similar to riveters. Some crafts, such as electrical workers and woodworkers, usually have earned about 20 to 30 per cent more on piece work than on day work. Chippers and calkers, also drillers and reamers, have earned about 30 to 50 per cent more on piece work.

In shop work proper, such as punching, shearing, and machine-shop work, machine-tool operators who do piece work have earned anywhere from 20 to 40 per cent over day workers, and sometimes more.

As a sidelight on methods in practice a few years ago in other countries, we will quote again from the article "Economic Phases of Foreign Shipyard Practices."

"In British yards, wage incentives or piece-work bonuses are limited almost entirely to the metal trades, with few exceptions. I was informed that last summer [1929], when the shipyards were operating below normal output, the piece workers restricted their output so as to make 1¼ or 1⅓ day's-work

pay; whereas in normal times with plenty of work they increase their output to time and a half, as a general rule. At one yard we were informed that in the engine works and machine shops the piece workers earn between 30 per cent and 50 per cent over day's pay.

"In the German and Dutch yards visited they believe thoroughly in the maximum of piece work, and the men are agreeable to this, so that they have time-study departments and work as much piece work as possible.

"One large company in Great Britain has bonus plans in all its plants for executives and officials and also for foremen. In the case of foremen the bonus plan in each plant is based upon a certain percentage of the profits for that particular plant. Formerly the foremen's bonus was based upon tonnage output, but this was discovered to be neither correct nor fair, and was changed a few years ago. In the case of company officials and executives, their bonus is based upon the total company profits, including all the five plants under the same ownership."

In the Author's first book, "Estimating the Cost of Work," a special chapter was devoted to the piece-work prices then in use (1915) in many shipbuilding operations and processes.

Only a few such prices will be detailed in this book; but more important than such details are a few basic figures and ideas which we wish to set forth.

In so-called Hull Work for vessels, whether Navy or commercial vessels, we shall always have certain "Operations by Hull Trades," somewhat as given in the quite incomplete list below, and we shall always have the difference between *continuous* work and *interrupted* work.

We will put down some operations for hull work, together with their two-letter symbols. The corresponding prices for years of 1915 and later appear in Appendix F (pages 177-218).

Symbol	*Operation*	*Symbol*	*Operation*
BO	Bolting Up		
CA	Calking	TP	Tapping
CM	Cementing	LO	Laying Off
CH	Chipping	PT	Painting
CC	Chipping and Calking	PL	Planing
CK	Countersinking	PU	Punching
CT	Cutting	RM	Reaming
CF	Cutting Off	RV	Riveting
CO	Cutting Out Rivets	SC	Scaling
CX	Cutting, Oxyacetylene	SH	Shearing
DR	Drilling, Pneumatic	TL	Tiling
DT	Drilling and Tapping	WC	Wood Calking

On the basis of the above listing and as a temporary standard with which to compare costs of operations in similar work, the simple set of piece-work prices introduced in Appendix F may be useful. It is hoped that, if carefully studied, especially the riveting schedules and the table of allowances for "scattered" work and for non-standard conditions, they will in a measure point the way for an estimator who has no standards, to set up his own standards of comparison, taken from his own data. Some of these prices may be low or high for a particular plant, as they were of course set in certain ship construction and repair plants, with consideration being given to the equipment and facilities, to the organization and management, and to local conditions and prevailing wages. In estimating the cost of any particular operation, we must first compare our own recorded data with these prices or costs, and get the average ratio between them. The simplicity of the classifications used (or of any other simple classifications) adds greatly to the rapidity and ease with which any ordinary estimate can be made for any number of units, however small, by using the judgment which comes from experience in classifying the conditions of the specific operation before us as to (1) accessibility,

(2) complexity, (3) contiguity of the units; by assigning to the operation before us a classification or class number which will represent the combination of these three conditions; and by not forgetting to discover (by plotting our own curves from recorded data) the mathematical law which gives the relation between *number* of units and cost, for the particular operation.

Since these labor costs or prices are introduced solely as comparative estimating data, no discussion will be made of the merits or demerits of this or any other piece-work system; but only the bare figures and accompanying rules and notes will be given. It may, however, be stated that where these prices were used the good workmen made an average of 20 per cent to 60 per cent over their usual day's wages, and that the labor cost of work was reduced from 20 per cent to 50 per cent over previous work of the same kind done by day work.

GENERAL CONDITIONS

1. The system must be acceptable to the employee concerned.

2. When the wage earned is less than a day's wage the cause must be investigated and the day's wage paid, if found not to be the fault of the workman.

3. A scale once fixed must not be made more severe unless conditions have changed through improvement in tools, etc., and any such change must be carefully investigated by the Manager and reported to the Department with the reasons therefor.

4. Any workman desiring to do piece work must sign a written application addressed to the Construction Officer, stating that the prices offered are satisfactory.

5. In case a workman is employed on piece work for less than eight hours in one day, the piece prices will be paid if the total amount done by him during that day is equal to or greater than the proportionate amount of the task set.

6. For all time during the day when a man works on other work than piece work, and for Saturday half-holidays or other holidays, the regular per diem rates will be used.

7. Whenever it shall be necessary for a piece worker to go over his work to make it satisfactory, he shall be checked out for such time as he is engaged in making the work satisfactory.

8. If during the remainder of the day, after having completed the work of making satisfactory piece work done previously, he works at the rate prescribed by the task, he is to be allowed piece work for the work he accomplishes during such remaining part of the day.

9. For example, if on the 18th, a man is engaged two hours making good piece work done on the 17th, he shall be checked out those two hours and allowed no pay for that time. The piece work thus made good is to be allowed him as piece work, provided that on the 17th he accomplished the specified task. If then during the remaining 6 hours of the 18th he worked at the specified rate per hour necessary to accomplish the task in 8 hours, he is to be allowed piece-work rate for what he accomplishes during the remaining 6 hours.

GENERAL NOTES

1. The daily task for any operation, except in a few special cases, specified otherwise, may be considered as the number of units which will earn 10 per cent more than regular day pay. Under favorable conditions, a first-class workman will be able to earn 50 per cent over day pay. For convenience, an output earning 57 per cent over day pay will be considered 100 per cent efficiency, so that piece-work prices will be paid for an average efficiency of 70 per cent, or more, for a pay period.

2. The prices given in Appendix F (pages 177-218) are intended to cover any amount of work, large or small, whether in the shops, on the ground or on ships at repair wharf or in

dry dock; that is, where the distances to travel between jobs successively assigned is not great. For work at a great distance an extra allowance for any necessary travel between jobs in excess of 300 yards will be allowed at the rate of two minutes day pay for each extra 100 yards, or fraction thereof.

3. All unit prices for an operation will be set strictly according to schedule, and all proper allowances (if any) covered by schedule will be determined in writing and agreed to by the workman before the operation is started, under the personal direction of the executive in direct charge of the piece-work system.

INCENTIVES FOR STAFF AND SERVICE PEOPLE

The piece-work or premium or bonus systems are fine for mechanics and other workers, and give them an incentive to produce. If the prices are fair, they know that they will receive a fair reward for better work. If they also know and are assured by the responsible management that the prices will not be *cut* as long as the existing conditions prevail as to tools, equipment and other facilities, then they will not hesitate to go ahead and produce.

That's all right for workers whose output can be directly counted or measured, such as in riveting, marking off, painting and many other operations.

But how about other good workers, whose output cannot be measured directly? Are they not entitled to some reward if their work is above the average? Here comes the problem of *how* to determine the results of their work and how to measure their output, indirectly, or by comparison, or otherwise.

The book, "Wage Incentive Methods," by Charles W. Lytle of New York University, published a few years ago and revised last year, is about the best publication tne Author has seen on the subject. It is not about shipbuilding, but most of the subject matter does apply to all industrial work, including

shipbuilding. In Appendix C are quoted a few paragraphs from this book.

In 1930 the Author was asked to present a paper on this subject before the American Society of Mechanical Engineers on Incentives for Staff Departments in a Shipyard. In the preparations of this paper he was assisted by Tom H. Blair, then head of the Time Study Department at the Newport News Shipbuilding and Dry Dock Co.

That paper had in it several things that may be of interest now, some thirteen years later, because the main principles are still carried out in that particular yard. Although changes and improvements have naturally been made, yet the idea continues to give a chance to staff people and to service departments of getting some bonus or extra money if they earn it, really *earn* it.

In order to express a bit more clearly, in shipyard words, how this can be accomplished, as fairly as practicable, it seems advisable to quote a few paragraphs from the paper just mentioned.

INCENTIVES AND BUDGETING

"Group bonuses can be applied to the work of service departments where one cannot measure separately the output of individuals on account of the great variety of functions performed by nearly every person in these departments. . . . The foregoing variable and uncertain factors make it necessary to establish, by study of previous cost records of service departments, some kind of budget or 'bogey' for the overall cost or output of these departments in quite a different manner from that in which it can be established for ordinary manufacturing plants making a uniform product of either standard or predetermined volume. The first thing, therefore, to be described will be the method of setting budgets or bogeys for the 23 service departments, all of which are now on some incentive

system, based upon these budgets. Each budget has been developed in the form of charts or curves based upon the fluctuation in the working forces or in the amount of service required by each service department.

"The General and Service Departments placed on incentive systems called the 'Group Bonus Plan' had over 700 employees of the total Yard force of about 6,000, as follows:

Department	*Approximate employees*
Cashier's office	15
Accounting & cost	29
Timekeeping	78
Tabulating	23
Employment	10
Janitors	18
Watchmen	50
Correspondence	25
Plant Engineers	25
Material department office	52
Storekeepers	80
Transportation	83
Drayage	27
Lumber storage	28
Steel stock storage	19
Production Division	88
Time Study	34
Order	18
Total participating employees	702

WHAT IS EXPECTED OF SERVICE DEPARTMENTS

"The bonus plans described are mainly based upon a good financial showing by the Service Department itself; that is, the department should render service at the lowest practicable

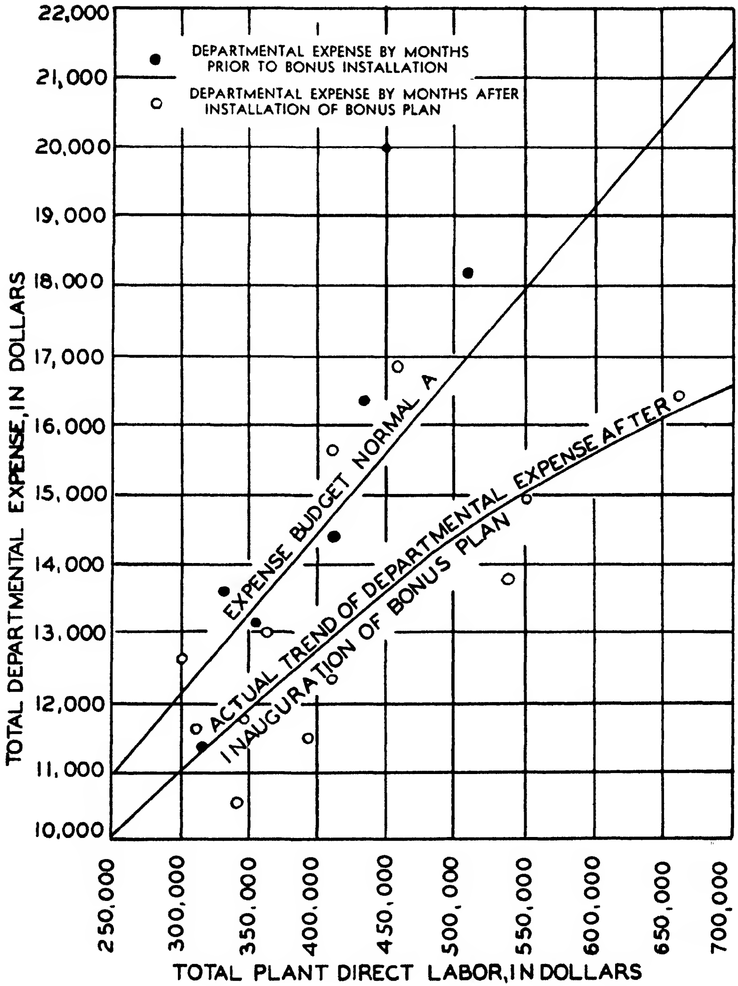


Figure (2): Chart of effect of group bonus plan on Transportation Department costs.

cost, provided that the service itself is not impaired. Quality of service is most important of all, whether engineering and design, storekeeping or accounting, or other service to the operative departments. The promptness and the reliability of service are also of the greatest importance. All service work should be planned and scheduled in detail, so far as practicable. The three main elements of good service, then, are (1) quality, (2) time, and (3) service cost. The measure of the result or effect of good service is the value rendered to, or benefit received by, the departments served. This usually shows up in reduced costs of direct labor and materials."

For some service departments, such as Transportation, Production Division and Time Study, the departmental budget was determined by a study of past costs of each department, which were plotted on charts similar to the one in Figure 2 for the Transportation Department, where the Total Plant Direct Labor in dollars is the abscissa.

Notice the similarity of this graph to that given in Figure 5, where the same idea was used for getting the "Preparation Cost P," corresponding to the "stand-by costs" for a Service Department.

For other service departments, instead of using Total Plant Direct Labor as the basis, we used other units. The "number of employees in attendance" being better than "labor costs" in some cases; and other units in other cases.

Many manufacturing plants have developed and used similar budget and bonus plans; notably Westinghouse Electric & Manufacturing Co., South Philadelphia, B. F. Goodrich Rubber Co. and the Dennison Mfg. Co.

The *bonus* feature of the plan outlined above was very simple. The savings under the department budget were "split" equally; that is, the Departmental workers and some of the

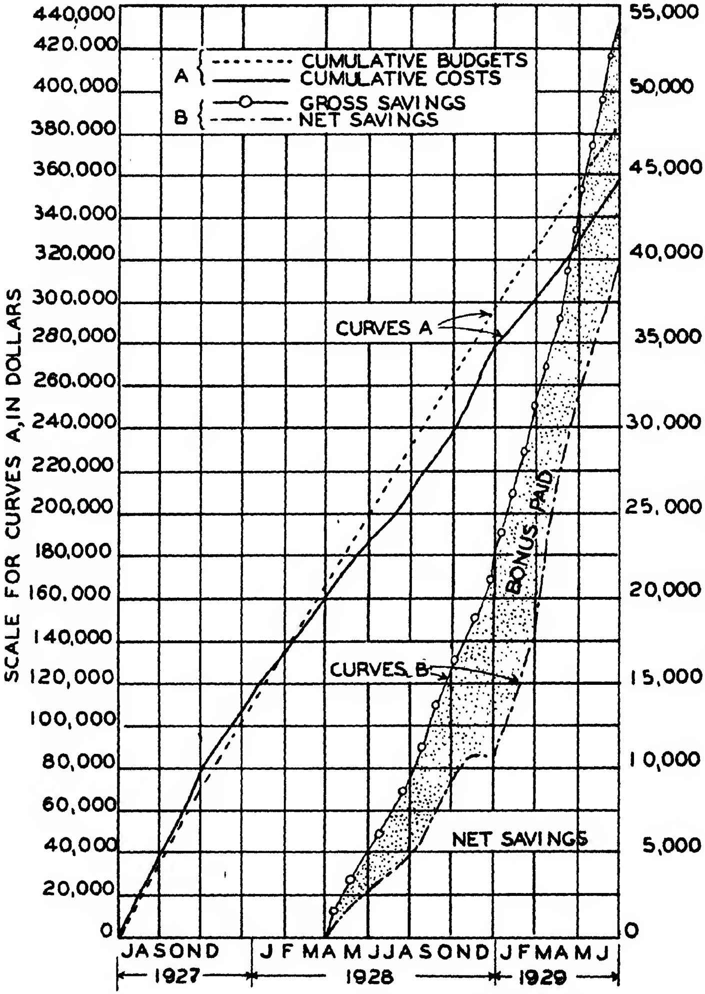


Figure (3): Another chart of effect of group bonus plan on Transportation Department costs.

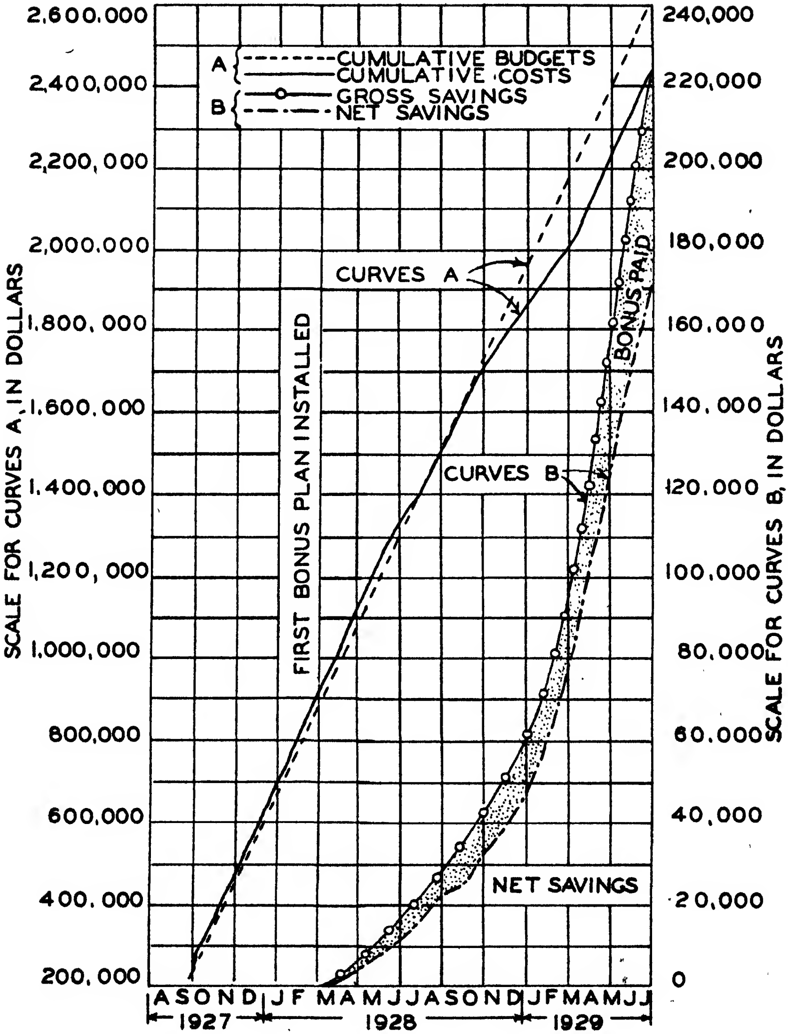


Figure (4): Chart of effect of group bonus plan on Costs in General and Service Departments.

Supervisors (up to a certain point) received half of the savings. This corresponds to the old Halsey premium system of wage incentive.

The *results* of any incentive system are what count, in the long run. The company is interested in reducing costs and saving money; the workers who do their part and render more good service and better production also get their share of the financial benefits.

Therefore this section will conclude with the results in one service department at Newport News, Transportation, and a general statement of the "overall results" for the whole plant. The number of employees in attendance in the Transportation Department when the group bonus plan was instituted was 142 compared to plant employees (direct labor) of 5400; 15 months later the Transportation Department figure was 83 compared to plant employees of 5430. The monthly department budget for this volume of work was about 18,000 (in 1928, 1929) and the bonus money paid was from $1000 to $1800 a month; but the net savings to the Company under the previous costs (before the bonus plan was inaugurated) were more than $2000 a month.

The overall results for all the service departments when on the group bonus plan, after only four months in operation for the last of these departments, were better than anticipated: a net saving in 15 months of $175,000.

No claim is made that the simple group bonus plan is highly scientific (in a shipyard especially), or that it is the ultimate best plan, but it is effective and can be installed in a fairly short time; and as time goes on it can be improved and even simplified.

All incentive plans, to be of mutual benefit to employer and employee, must be based upon mutual confidence and a sense of fairness; as fair a system as can be devised must be the goal.

Chapter 7

Cost Estimating by Large Groups

WHAT IS AN ESTIMATE?

The word "estimate" is used in several different senses, and in dealing with the cost of work it is necessary to confine our discussion principally to one specific definition or meaning. Those who require or seek estimates of cost need them for a variety of reasons or purposes, and these various purposes correspond with the kind of estimate required, for example:

To estimate may mean: To make a "rough" approximation of probable cost. This is the only kind of estimate possible when the specifications are not exact as to the extent and nature of the work which is contemplated. Such estimates as this are required by Congress upon which to base most of the appropriations. Such an estimate is required for large projects or for contemplated work not definitely decided upon, where the approximate outlay may determine whether the project can be financed properly, and whether it is worth while to go to the expense of making more detailed investigation and of making accurate estimates.

To estimate may mean: To fix the value by comparison and experience; to calculate; and usually to make this calculation by utilizing all available comparative data. If an estimate is made for a prospective customer, it is usually in the form of a "bid," submitted on a regular form of proposal; and if the estimate is accepted and approved, it becomes the contract price. This form of estimate must be made and checked with great care; and it will be of advantage to be able to submit an estimate of this kind without undue delay. Hence both accuracy

and promptness are desirable. Such estimates or "bids" are made by adding to the estimated *cost of production* a sum for marketing the product and for *profit.*

The term "estimated cost of work" will be used to indicate the probable actual cost or outlay to the contractor, which is required for a specified production. Profit and selling expense will not be included. Total cost is composed of labor, material, and incidental expense. Attention will be especially devoted to estimating the *labor.* Estimating the cost of material presents no difficulty to the experienced estimator after a complete list of the material required is prepared. The "incidental" expense can be allowed for by a number of different methods, depending upon the degree of accuracy desired, and upon the kind of cost-keeping system in effect in the plant. The practical application of these methods to estimating the incidental or overhead expense will be discussed briefly.

In estimating or calculating probable costs (which must be done by comparison and experience), the estimator is bound to use some *standard* of comparison, not a fixed or immutable standard, but nevertheless a standard or guide; whether such standard is the written record of actual previous costs of identical or similar products, or whether such standard exists only in the mind or imagination of the estimator.

WHAT IS A STANDARD?

Funk & Wagnalls' Standard Dictionary says a standard is: "Any type, model, example, or authority with which comparison may be made; any fact, thing or circumstance forming a basis for adjustment and regulation; a criterion of excellence."

In the art of estimating, it is only in determining what costs *should be,* if we eliminate preventable waste (or, using the term introduced by the famous industrial engineer, Harrington Emerson, it is only in "predetermining costs"), that we establish a standard which is "a criterion of excellence." In estimat-

ing what costs *will actually be,* we use for a standard of comparison the type or example of past performance which represents the *average* cost of work, under standard conditions. By thus using a *standard* estimate for each unit (whether the unit chosen be an object or an operation), based on the cost of a standard number of units under certain conditions taken as standard, the estimator can proceed methodically to classify and study all cost data and estimates with reference to such standard.

By this means, each and every cost or estimate can be compared to some standard cost or estimate; and data gradually collected by which the best possible estimates can be skillfully made for any item of work that may arise.

The pursuit of this practical application of data and knowledge by estimators, and the devising of rules which govern the average costs of all units, dependent on the variables of (1) Number of units, (2) Size of unit, (3) Classification number, will become an *art* instead of a haphazard guessing process.

THE ART OF ESTIMATING

The usual methods of estimating are many and diversified. Large volumes have been written on the subject; many books for each class of building work, but very few books for repair work. All these works are valuable, and should be read and studied before the ambitious estimator or task-setter undertakes to systematize his data and to benefit by the methods set forth briefly in this modest volume.

A thorough technical knowledge of his own business is assumed of all who will be interested enough to read this volume, and a knowledge and experience in planning work in more or less detail, including making itemized Bills of Material. The accuracy and rapidity with which a good estimator can prepare estimates depend upon the accuracy and thoroughness of the *data* which the *records* for the particular plant furnish,

and upon the convenience and handiness of the data arranged, tabulated or plotted in compact form, properly indexed and classified.

The actual figures given are not intended to be accurate for any individual plant other than the particular shops or plants from which the data were obtained. But by reference to the scale of wages in appendix the estimates can be reduced to the hourly basis to compare with other plants. That is, the main point to emphasize is that *each plant* must collect *its own data;* and the writer believes that the analysis, arrangement and concise record of such data along the outlines indicated will materially assist estimators or task-setters, or superintendents,

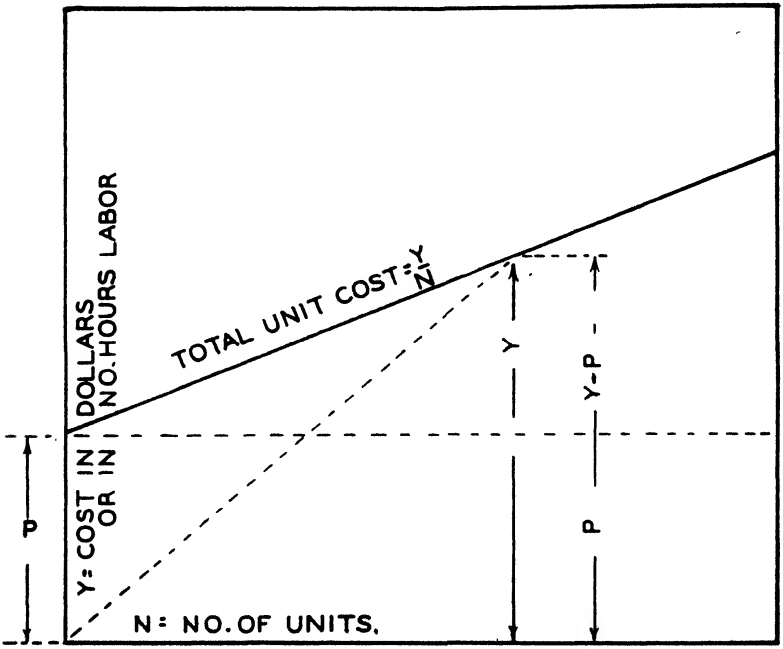


Figure (5): Simple graphic expression of cost data.

in preparing accurate estimates for new work or repair work with facility, and estimates will be in a convenient shape for comparison with actual costs, as well as form the preliminary basis for a piece-work or bonus system.

GENERAL METHODS BY CURVES OR GRAPHS

All estimating data of value can, as a rule, be reduced to curves, thus placing in compact form on one sheet of paper as much information as several pages of figures would take up. Curves also show many important facts and observations which are not so readily impressed on the attention as other methods. This particularly applies to the separation of estimates for labor into the two main elements: (1) Cost of preparation for doing work (i.e., aside from the actual operation of the machine or workmen in "producing"), including travel to work, setting up, removal, etc., (2) Cost of operation.

The simplest form of curve, which fits a very great variety of operations and jobs, shows the number of units performed as abscissae and the cost (or number of hours' work) as ordinates. Such a curve is shown in Figure 5.

The ordinate at the origin is the cost of preparation (P). This forms a very considerable part of the total labor cost. For a day's work it often amounts to over half the total labor cost. Hence its importance in estimating the cost of work must not be overlooked.

The straight-line curve in Figure 5 represents fairly well the cost of *simple* operations in repetition manufacturing work, e.g., where the "operating cost" of machining, aside from "preparation cost," increases *directly* as the number of pieces manufactured. This condition, however, seldom obtains, for many practical reasons mentioned later, and the form of the actual curve for recorded costs will, in most cases, be somewhat as shown in the curve, Figure 6, which may be compared with the straight-line curve in Figure 5.

PRACTICAL MEANING OF THE CURVES

These simple curves merely show graphically what everyone knows, but which is so frequently not allowed for properly or correctly by most estimators, namely: That the unit cost depends absolutely upon the number of units performed one after the other (up to a certain practical limit). Up to this

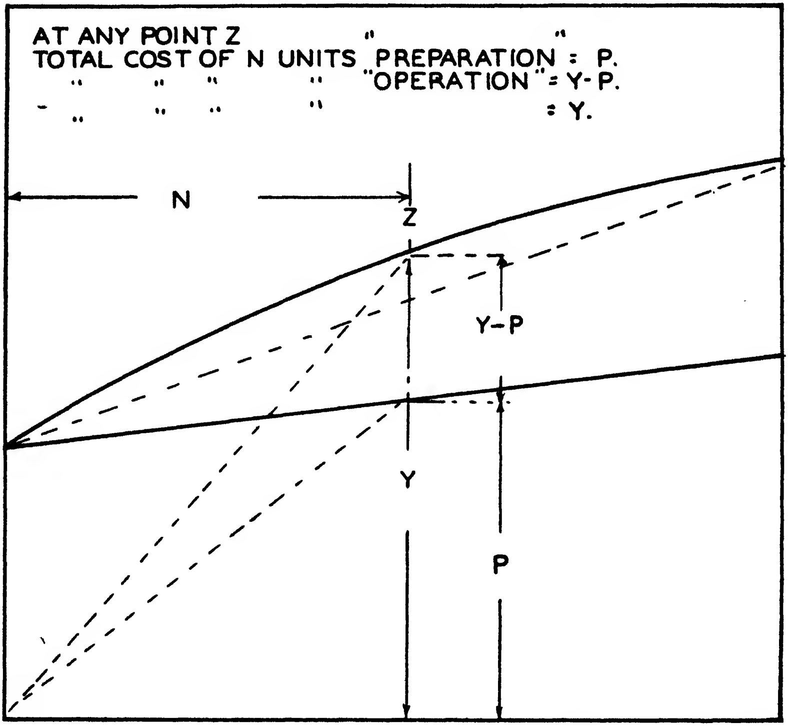


Figure (6): Usual form of curve of actual unit costs.
Unit cost of preparation = P ÷ N
Unit cost of operation = (Y − P) ÷ N
Unit cost of total = Y ÷ N

number there is a determinable relation between unit cost and number of units; and this relation can be expressed mathematically. This is true not only of manufactured articles, but it also holds good for all manner of operations. The investigation of this relation for all classes of work constitutes an important function for all estimators. By plotting fair curves, from actual cost records, showing graphically the number of units in each operation of a certain class as abscissa and the total cost of the operation as ordinate, we get at once the estimated cost of any desired number of units. We do not have to even bother about estimating the unit cost.

The piece-work prices which appear later as estimating data were set with this principle in mind; and for a small number of units, or "scattered work," which comprises such a high proportion of repair work, an allowance was made for "preparation," up to about four hours' average output at ordinary day work.

NEW CONSTRUCTION WORK

For manufacturing work or new construction, the records of total costs of *objects* are, of course, the most reliable and valuable data for estimating on identical objects. In case of minor differences in design, allowances can readily be made for corresponding differences in cost. When it comes to an entirely different design, however, estimates must be based on the elements or divisions of work which go to make up the total costs of objects. For example, in ship construction, the usual divisions comprise Steel Hull proper, Hull fittings, Boilers, Engines, Auxiliary machinery, Piping systems, Plumbing work, Woodwork, Painting,, Equipment, etc. And these are still further subdivided. For example, ordinary steel in Hull proper into (a) Shell plating, (b) Framing, (c) Bulkheads, (d) Decks, (e) Bridges, (f) Foundations for machinery, (g) Inclosures, (h) Metal masts and spars, (k) Rivets, (l) Welding rod, (m) Nonconducting sheathing and ceiling.

These elements are estimated for separately, usually on the *per pound* basis, by comparing actual records of cost per pound for previous vessels built at the plant, where such records are available, provided they are accurate. Frequently cost records are less accurate than careful estimates. In many cases, however, such comparisons are not accurate, due to different design and arrangement of any previous vessel, and we can either allow for these differences more or less by offhand judgment, or we can separate these groups or items still further, until we arrive finally at a fair means of comparison with previous costs of small units. These methods of estimating on new work are very reliable where previous costs are accurate and comparable with the new conditions, and where no appreciable changes or improvements in methods of doing work have taken place since the previous work was completed.

There are, of course, many other units of comparison besides the pound or ton, for all classes of new work; such as the square foot, the square, the running foot, the cubic yard, the number of units (as number of rivets, number of holes punched, etc.). That is to say, units of length, area, volume, or weight.

The final or ultimate separation into units comparable with previous work may result in comparison of prime elements or "operations," that is, the successive steps required to construct each part of the whole; such as laying off, marking, punching, shearing, machining, assembling, erecting, riveting, calking and testing. It is with this final method of analysis into prime elements that we have to deal in the case of *repair work,* in most cases, for the reason that we seldom have two repair or alteration jobs of identical nature and scope.

REPAIR WORK

There are many difficulties, seemingly unsurmountable, in the way of accurately estimating on repair work, especially ship repair work. Previous records of *total* costs are seldom

of much assistance, as identical repair jobs seldom recur, and conditions are never the same. Total costs of similar jobs, however, serve as a guide or check on the detail estimate. They should not be accepted without careful analysis and comparison as to the character of work, and conditions under which performed.

Among the difficulties that attend estimating on repair work may be mentioned the following:

1. Extent and nature of repairs unknown in detail until the work is under way; that is, before estimate is made.
2. Accessibility of the work, whether in the shop or in the field; work may be overhead, or in closed-in or cramped places.
3. Complexity and difficulty of the work compared to some assumed *standard* condition; work may be on plain plates or shapes, or on curved or irregular surfaces, or on beveled shapes.
4. Continuity or contiguity of the units which comprise the operation, the amount of shifting of tools or position of the workmen which is required.
5. Physical or natural conditions surrounding the work, such as weather, light and heat; also the possibility of efficient supervision, considering the locality of the work and number of men employed to advantage at one time and place.

As to the first-named difficulty, namely, lack of definite specifications because impossible to make them, it may be said that this makes an accurate estimate impossible; in fact, no *real estimate* can be made, but only a rough guess. In such cases, it is a pure waste of time trying to guess accurately, and it would be better in all such cases not to make an estimate at all until the work of dismantling or overhauling was under way sufficiently to determine exactly what repairs had to be done. If a "bid" *must* be submitted on this class of work, it will be the best practice to bid on actual cost plus a fixed profit (either a lump sum profit or a percentage of cost).

The other difficulties enumerated above of estimating on repair work may be called conditions of a variable nature, and as such may be classified to cover all manner of repair jobs sufficiently for ordinary estimating purposes. The accuracy of such estimates will be dependent upon: (1) The thoroughness with which the detailed observations of similar operations under various conditions have been obtained and recorded. (2) The skill and judgment of the estimators in classifying various conditions, and in assigning the particular operation being estimated upon into the right class. (3) The skill of workmen employed, system of pay in use, and methods of organization used in the shop; that is to say, dependent upon the efficiency of labor; and (4) The judgment of the estimators, based upon proper records of past work of a similar nature, in making allowances for wholly unforeseen contingencies or extra minor work not planned for originally. This latter factor may in ordinary ship repair work run as high as 20 per cent of the total labor cost for some classes of work. For small jobs, the factor will naturally be much larger than for large jobs. On the average, counting all manner of alteration and repair jobs, large and small, for a whole year, this factor should not exceed 10 per cent of total cost and can be estimated within 1 per cent of total cost by an experienced estimator.

CLASSIFICATION OF VARIABLE CONDITIONS

By this is meant what is commonly known as standardization of conditions, or of operations. In manufacturing work standardization has progressed to such an extent that fairly accurate estimates of cost of operations, or of a fair "time allowance" to perform an operation, can be readily made. These estimates can be based on extensive observations, motion studies, and detail cost records. In repair work, however, the problem is far more difficult; but wherever it has been studied and partially solved, the results have been so satisfactory in the

way of increased efficiency, and so convincing as to the practicability of standardization of all manner of operations, that we may look some day to the serious consideration of the establishment of a Bureau of Trades under the United States Government, as proposed by Mr. Frank B. Gilbreth in "Motion Study," such Bureau to have two main tasks: (1) To subclassify the trades. (2) To standardize the trades. Mr. Gilbreth contends that

"This subclassifying of trades according to the types and grades of motion that they use, or according to the brawn, brain, training, and skill required to make the motions, will cut down production costs. It will raise the standard of all classes. It will do away with differences between employers and employees. It will eliminate unnecessary waste. It will raise the wages of all workers. It will reduce the cost of living."

When it comes to repair work, an example of what can be done, and has been done, toward standardization is seen in the railroad repair shops of the Santa Fe, where 23,000 operations had been standardized as far back as 1914, and estimates thereby made upon which a complete bonus system was based.

COST DATA ON NEW CONSTRUCTION

Before taking up the classification of elementary operations in shipwork, which we will later do from an estimator's standpoint, and make the nomenclature as simple as possible, let us first consider the main physical divisions of a vessel, and take a common classification for estimating the value of new construction by the pound. The figures given on pages 177-194 are based on 1914 and are for direct *labor* costs only, for hull work, of several types of vessels; and they are given mainly to show how widely these unit costs varied and still vary with

different types of construction, and for the different classes, or groups, of a vessel's structure. Beyond this purpose they could be used for anything except "rough" estimates, as each plant has to collect its own figures, and tabulate them. This may be a convenient method of tabulation, for each design of vessel built. A study of the different designs, in connection with the various unit prices thus tabulated, would enable the estimator to account for any considerable differences in unit costs due to design, and to strengthen his judgment in checking over new estimates for new work.

Since these labor costs per pound were for vessels built mostly by day work, they are considerably higher on the average than we would expect for work done entirely by a piece-work, bonus or contract system.

DIRECT LABOR COSTS PER POUND IN CENTS
[See Note at end of table.]

Group Number	Items	I Battleship	II Destroyer	III Collier	IV Coal Barge
7	Ordinary steel in hull	4.6	7.7	2.1	1.1
	(a) Plating, outer and inner bottoms	2.1	4.0	1.1	1.0
	(b) Framing	4.1	7.0	1.5	0.7
	(c) Bulkheads	4.7	8.0	2.2	1.1
	(d) Decks	3.0	6.0	1.4	0.6
	(e) Bridges, hammock berthing and cofferdams	9.7	15.0	3.3	
	(f) Foundations for armor, turrets and guns	5.9			
	(g) Work around secondary battery, etc.	15.1	15.0		
	(h) Foundations for machinery	7.3	10.0	4.3	
	(i) Inclosures	10.4	15.0	2.0	
	(j) Metal masts and spars	16.0		3.0	
	(k) Rivets	11.1	25.0	12.1	11.0

Group Number	Items	I Battleship	II Destroyer	III Collier	IV Coal Barge
8	Steel castings and forgings forming structural parts of hull	5.3	16.1	1.7	
10	Deck pillars or stanchions	5.5	12.1	1.7	
11	Deck planking and wood in docking and bilge keels	6.1	8.0	4.0	1.1
12	Linoleum, tiling, etc.	1.4	8.0	1.2	
13	Joiner work	30.9	30.0	8.0	
14	Carpenter work	11.7	12.0	5.0	
15	Wood ladders	39.4		15.4	
16	Wood masts and spars	24.6	35.0	16.5	38.0
17	Metal ladders	13.1	25.0	3.8	4.0
18	Paint, cement, etc.	11.5	13.4	4.9	2.5
19	Turret-turning machinery, roller tracks, and rollers	9.0			
20	Fixed ammunition-hoist machinery and gear	19.2	20.0		
21	Rudder and steering gear	5.1	13.8	3.4	
22	Cranes, davits, and other gear for handling boats	11.6	10.0	8.3	3.0
23	Coaling gear	10.2		10.9	
24	Pumping and drainage, and sea connections	33.7	40.0		
25	Plumbing work, including fresh and salt water systems	25.5	25.0	7.9	
26	Ventilation	34.9	51.0	17.6	
27	Anchor and cable gear	6.8	13.3	4.1	2.3
28	Warping and towing gear	6.3	15.0	1.3	0.9
29	Hand rails and awning stanchions, canopy frames, and hatch cranes	28.2	30.0	17.1	
30	Air ports, deck lights, and light boxes	19.0	25.0	8.7	
31	Watertight doors	15.2	44.2	16.8	
32	Nonwatertight doors	28.7	18.1	17.2	
33	Manhole-covers, scuttles, etc.	21.4	30.0	2.6	0.8
34	Miscellaneous hull fittings	15.3	25.0	13.3	

Note: The above U. S. Navy Department "Groups" are still in use; the figures above are for the year 1914; the present figures would be about three times as much.

The four types of vessels which are selected for comparison are all naval vessels, viz.:

(1) Battleship of the "New York" class.
(2) Torpedo-boat destroyers, 1,000 tons.
(3) Collier of the "Jupiter" class.
(4) Standard 500-ton navy coal barge.

There are several other items in ship construction for which the costs are not given, some of which are peculiar to warship construction. These items cannot be estimated by the pound with any degree of satisfaction, for example:

Armor and armor backing.
Nickel-steel protection for hull.
Electric generating plant.
Electric wiring throughout ship.
Means of interior communication.
Installing ordnance and ordnance outfits.
Installing furniture and equipment.

In addition to these items there are certain *general items* of expense incident to building a vessel which are ordinarily charged *directly* to the cost, instead of as an overhead charge. The cost of these general items varies greatly with the organization, equipment and local conditions, and a comparison of such costs for two plants is of no great value for estimating purposes. In some systems of cost keeping a large portion of some of these items does not appear as a direct cost but as a part of the overhead or incidental charges.

These general items are classified as follows:

No. 1.—General superintendence, office expense, insurance, freight.
No. 2.—Drafting work (5 to 10 per cent of total labor).
No. 3.—Laying down in mold-loft.
No. 4.—Preparation of slip, cribbing, and scaffolding.

No. 5.—Preparation of launching ways, and launching ship.
No. 6.—Trial trip expenses, and docking.

It will be seen from the wide variations in unit costs for the groups or items above, which are in common use, that these groups are not the best that could be selected for estimating purposes. A more logical grouping for estimating or cost keeping purposes would be based upon the character of *materials* and the work upon each distinct class of material subdivided into the work by trades. Such a classification has been used abroad, and was first described at some length by Mr. L. Peskitt in a paper read before the Institution of Naval Architects at Glasgow in 1913. (See *Shipbuilding and Shipping Record* of June 26, 1913.) Mr. Peskitt outlines a method whereby the cost of steel work and such material can be determined, which is generally on the basis of weight.

He states that

"Shell and deck plating would be dealt with first, and then such other plating as occurs throughout the structure. Thereafter, and in a systematic manner, the quantities of angle sections would be taken out. An estimate would be made for the various classes of forgings and castings. . . . Both in computing the cost of steel work and carpenter's wood, the cost of material is kept separate from the cost of wages."

Another way, and frequently a more accurate way, to estimate on the structural steel in hull proper, is by the total cost of processes or operations (under each subdivision or group) which can be done very readily if the jobs have been planned out in detail. For example, on standard navy coal barges, the cost of these operations at one navy yard on the shell plating group was as follows:

TWO STEEL COAL BARGES

Capacity 500 tons each

Group 7a { Shell plating, bottom and side.
Weight including rivets 215,000 lb.

Operation	Units	Number of units	Cost of operation	Per cent of total cost	Cost per lb. of total job (in cents)
Templating	Sq. ft.	13,000	$ 65	3.0	.033
	Lin. ft.	1,000	7		
Laying off	Sq. ft.	13,000	160	7.2	.080
	Lin. ft.	1,000	15		
Punching	Holes	104,000	200	8.2	.093
Shearing	Lin. ft.	480	5	0.2	.002
Countersinking	Holes	36,000	60	2.5	.028
Drilling	Holes	500	7	0.3	.003
Planing	Lin. ft.	4,000	40	1.7	.018
Erecting	Lb.	210,000	140	5.8	.065
Bolting up	Bolts	19,000	240	10.0	.110
Reaming	Holes	48,400	220	9.0	.100
Riveting	Rivets	48,400	1,160	48.0	.540
Calking	Lin. ft.	1,300	15	0.6	.007
Smith work	Lb.	18,000	85	3.5	.040
Total	Lb.	215,000	$2,419	100.0	1.125 cts.

Note: The above 1915 cost figures should be multiplied by about *three* to represent present figures (1943).

Each job or group of a new vessel can be estimated upon in this manner and all these estimates tabulated by jobs and by operations, all on one large sheet of paper. During the construction of the vessel, this sort of an estimate would be useful both to the contractor and to the customer (or inspector), in estimating monthly the value of the vessel as she stood on the stocks. The progress of work in tenths and in dollars could be checked off both by jobs and by operations.

NEEDS FOR GOOD ESTIMATES

Good estimates of production costs are needed by the superintendent or manager in order that they may fix the selling cost of the product properly, or know what the profit will be if the selling price is practically fixed by competition or by the state of the market. Good estimates are made by accurate comparison with the previous costs, allowing for any special changes in equipment or methods, and hence a good estimate becomes a standard with which to compare the actual cost when the production is completed, and thus show any increase or decrease in efficiency of the plant in respect to the particular product. If the estimate is made by operations, the change in efficiency of operations can be localized and investigated. It is of no benefit to know that inefficiency exists unless it can be localized, investigated and possibly remedied.

Good estimates of labor costs are needed both by the management and the workman, in order to mark the efficiency of each workman justly. When there is no systematic way of keeping records of individual efficiencies, there is sometimes a temptation for supervisors to show favoritism; and in any event, no one can judge of men's efficiencies correctly without detail records.

Good estimates of labor costs, or of what constitutes a fair task for a good workman, are essential for the establishment and successful working of any piece-work or profit-sharing system of pay. Practically all the troubles which have arisen and will arise in the usual form of piece-work systems can be traced to poor estimates of what constitutes a fair task for a given time, resulting in piece rates being reduced later on, when the error in the original estimates is discovered.

The best system of determining what overhead costs are, and the method of distributing them to various production orders, are based upon estimates.

So we see that all records of efficiency, rating of workmen, and the question of wages and profit are all dependent upon *estimated standards.*

In a plant where no attention is paid to standards or to good estimating, how often we hear a workman reprimanded for not doing more work, when the supervisor or manager who complains has no real, definite, idea whether the workman is doing a fair day's work or not. Frequently these complaints occur at a time when the workman is taking a short "rest"—a legitimate and proper rest from exacting and strenuous physical exertion, such as forge work, riveting, or heavy lifting; the workman is reported for "loafing," whereas the actual record of "output" for the full day's work if compared to a standard for a good day's work, would show a high efficiency of the workman. On the other hand, low efficiency can be readily detected from observing the efficiency records day by day, the causes can be properly and consistently investigated, full justice obtained, and the causes eliminated in whole or in part.

Knowledge and facts thus replace guesswork and bluff, a sense of fairness and the square deal prevails, and both the employer and employee benefit by the increased efficiency and personal reward for merit. When a workman is assigned a job, and the material, tools and specifications are all provided for him beforehand, how much better it is to know when he starts how long it ought to take to complete, with a fair degree of accuracy; and if the workman does the job in less than the estimated time, to reward him suitably, not only for his application and skill, but also for his cooperation in doing the work the best way?

In fixing or estimating what reward the workman is entitled to for performing a task in less time than he would *without* this reward or incentive (and it is only human nature to accomplish more with the hope of reward), the management naturally figures how much it can *afford* to pay extra to the workman as

his share of the profits for his increased efficiency, and at the same time share the profits due to the extra efforts and expenses of the management. In figuring these rewards or profits, due to increased output, the gain to the management in the time saved is frequently overlooked or underestimated. Time saved is money saved, both directly and indirectly. The overhead expense or incidental charges incident to any operation—and particularly a machine operation—is about the same each hour; not exactly the same, but it varies more directly with the time than it does with any other single element. Hence a saving in hours of labor is a corresponding saving in dollars to the management.

There are several well-known methods in use of estimating this very important item of reward or profit; and of giving to the employee an equitable share. The very variable human factor enters so much into this very human and practical problem that it is not capable of exact solution. A good or satisfactory solution in one factory, under a certain form of management and with certain local conditions, would be a failure in another factory.

Chapter 8

Cost Estimating by Operations

SHIPYARD PROCESSES AND OPERATIONS (COMPARED TO MANUFACTURING). It has been seen that in either repetition manufacturing work, or in new construction work, we can sometimes classify costs by the total costs of *objects* or parts, specified by the technical name of the object, article or part. We can also go further and classify costs by operations—independently of the *names* of articles or parts, except so far as needed to define the conditions or character of the operations as regards (1) accessibility of the work, (2) *difficulty* or complexity of the work, compared to some simple basic or *standard* degree of complexity, defined by an example, (3) *continuity* of the units comprising the operation, as determined by the number of units (whatever the unit of measure chosen) which can be performed one after the other wthout stopping or shifting position of men or equipment.

We can go still further, and subdivide or analyze each of these three main groups of condition factors into its elements, somewhat as Mr. Gilbreth describes in his "Motion Study"—a book that each estimator should read diligently. The extent to which it will be profitable to analyze operations will depend somewhat upon the use to which we wish to put our data, and upon the expense involved in making the analyses. For operations which seldom recur, even in general form or character, to say nothing of those which never recur in identical form, extreme refinement will seldom pay.

PLANNING AND ESTIMATING BY OPERATIONS

By the word "operation" we usually mean, in manufacturing or shipbuilding, a very definite piece of work for a particular

trade with a particular machine or tool. It may take several such "operations" to make up what may be termed a "process." The entire *process* of riveting, for example, takes several operations such as:

(a) Reaming the holes between the bolts
(b) Driving the rivets into the reamed holes
(c) Changing the bolts from the unreamed holes to reamed holes
(d) Reaming the holes from which bolts were removed
(e) Driving rivets in these newly reamed holes
(f) Testing the rivets, and marking the "cut outs"
(g) Re-driving the "cut out" rivets

There are variations to these operations, and the practices are not the same everywhere.

With these definitions in mind, we can go ahead with the "operation" planning, bearing in mind that the same idea also covers "process" planning and estimating.

If an operation is to be performed by day work, the relative efficiency of the day workers and of piece workers must be taken into account in estimating. The cost of day work will average between 25 per cent and 50 per cent greater than piece-work cost under the ordinary form of management. The actual figures for estimating this percentage, however, must be obtained from the detail cost records, as they will vary with each plant, and with each class of operation. The individual records of the efficiency of each workman, on both piece work and day work (which should in time be furnished by an efficient planning and costkeeping system), will give these data for any particular job. It would, of course, be desirable to have every operation performed by piece-work or by some other profit-sharing system, provided the prices were properly fixed by the most thorough observations practicable, or possible, from an economic standpoint. This would also make estimating simple and easy. This condition, however, cannot be realized in a

short time on complicated work, and it may be many years before even the major part of miscellaneous operations "in the field" can be standardized. Furthermore, men are averse to doing a small number of units of work, or scattered work, by the piece or "operation" unless thoroughly convinced that they can make good money by it, and that they can be assured of continuous employment.

It is with this feature of the "Art of Estimating" and collecting estimating data that the "Art of Management" is so intimately connected and concerned. The estimator has to look to the good manager, with progressive but fairminded ideas, and of broad experience, for the methods, means and assistance required to collect all the valuable data needed for estimating and planning work properly.

Since the "outside" work (as distinguished from "shop work") in a shipyard is probably the most difficult of all work to estimate on, due to lack of standardization, and as it comprises more than half of all ship work, an attempt will be made to indicate briefly to what degree it seems practicable within a few years to standardize the most difficult of all classes of work, and to see what beneficial results are likely if not certain to follow every intelligent effort in this direction. In the matter of planning work and of providing equipment, materials and clear instructions for the workmen, experience seems to show that the greater the difficulty of so doing the greater the need.

Planning of work by operations or consecutive steps may be of a very general nature, simply designating *what* is to be done by each workman or group of workmen, in logical sequence; or it may be of a very scientific nature, by still further subdividing each step or element performed by one man or group into its distinct components or elementary operations, and not only state *what* is to be done but also exactly *how* to be done; these elementary operations may be the subject of accurate and ex-

tensive time-studies and motion-studies. No discussion will be entered into of the merits of either method, as we are at present concerned merely with the obtaining of the best estimating data our present methods of performing work and collecting cost data will furnish us. What we desire to find out, as far as the estimating of costs is concerned, is what will be the probable actual cost of the job before us, for which we have definite specifications.

ESTIMATING BY OPERATIONS

Estimating and planning by operations (or at least by processes) as distinguished from over-all or general planning takes considerable pencil work and a few extra people to do this work. So it may be asked: Does it pay? The answer to this proper query seems to me about the same today as it was twenty-eight years ago, when I said:

"As to the extra cost of this method of estimating, by operations, there is no real extra cost. The material has to be ordered by some one anyway, the steps to take and the *sequence* of operations have to be determined by some one, and the proper date of completion should be determined by some one. It happens that in planning and estimating work in this way, the man who assists so materially in these things is the man with the recorded data, which enables him to do it right; and incidentally he relieves foremen, leading men and workmen of unnecessary clerical work, annoyances and interruptions in their own important and legitimate work. There is always a total net saving in every job properly planned and scheduled."

From our previous discussion, and from the more specific remarks below upon the preparation and use of curves in estimating, the method followed in estimating the labor costs of

operations will be understood. Standard curves, representing average performances, are plotted from recorded data; separate curves for various kinds of operations, and a separate curve (usually) for each classification under each general operation. The proper unit to choose as the basis for plotting curves requires close study. As there are a great many variables which affect the cost of an operation, we have to select the most important or determining variables for our units. For example, in handling weights, we may select *weight* times *distance* (number pounds times number yards) as the unit (plotted as the abscissa). The number of pieces of material handled is taken care of by the *condition factor* for *continuity*, which is allowed for in the *class* or classification number.

Chapter 9

Preparation and Use of Curves

Curves which represent actual costs of operations, and which show the relation between the number of units and cost (and incidentally show the average cost of "getting ready," or preparation), are easily plotted from the records, if a good (or even fair) timekeeping system is in use, which will give either the time in hours (or minutes), or the labor cost, of each operation. If a separate record card, or time card, is used for each operation, these cards can be sorted out by the general operations—such as templating, punching, riveting, etc.; then still further grouped into *classes* under each operation. The use of symbols on operation cards will facilitate this work. Supposing we have thus segregated a number of records for riveting, for example—and that each record is specific and in detail as to the character and conditions of work (which determines the *class number*), as to *size* (diameter) of rivets, and gives the *number* driven. The record must show these three things, for any operation whatsoever to be of any value as estimating data, and if it does show them, the record can be easily plotted.

Suppose the records we have selected out as above are for ¾-inch ship riveting (day work with pneumatic hammers), and that the essential parts of some of the records we want to plot are as follows:

Record No.	Location of work	Class No.	No. units	No. hrs.
1	Inner bottom	4	275	10.6
2	Manhole covers	5	30	2.5
3	Bulkhead	3	993	27.7

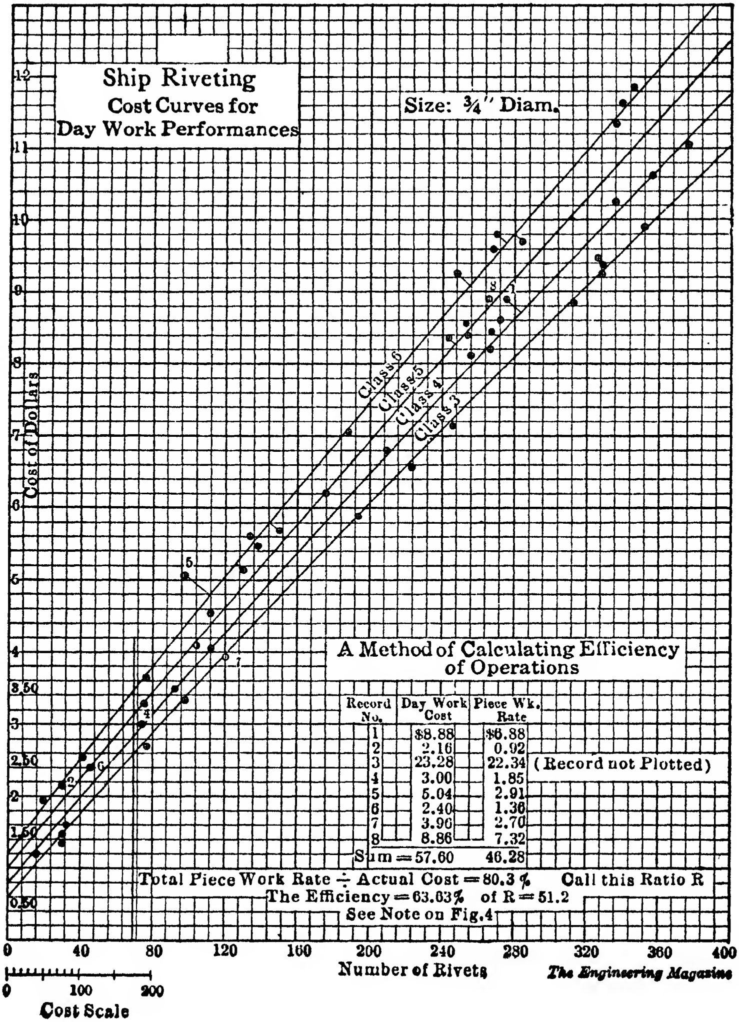

Ship Riveting
Cost Curves for
Day Work Performances
Size: ¾″ Diam.
Cost of Dollars
Class 6
Class 5
Class 4
Class 3
A Method of Calculating Efficiency of Operations
Record No. | Day Work Cost | Piece Wk. Rate
1 | $8.88 | $6.88
2 | 2.16 | 0.92
3 | 23.28 | 22.34 (Record not Plotted)
4 | 3.00 | 1.85
5 | 5.04 | 2.91
6 | 2.40 | 1.36
7 | 3.90 | 2.70
8 | 8.86 | 7.32
Sum = 57.60 | 46.28
Total Piece Work Rate ÷ Actual Cost = 80.3 % Call this Ratio R
The Efficiency = 63.63% of R = 51.2
See Note on Fig.4
0 40 80 120 160 200 240 280 320 360 400
Number of Rivets
The Engineering Magazine
0 100 200
Cost Scale

Figure (7).

Record No.	Location of work	Class No.	No. units	No. hrs.
4	Shell plate	4	74	3.6
5	Ammn. trunks	6	97	6.0
6	Boat crane	5	45	2.9
7	Main deck	3	120	4.7
8	Fender guard	5	266	10.6

All these records and all other records for ¾-inch riveting could be plotted on one sheet—the number of rivets as *abscissae,* and the number of hours (or cost, if preferred) as *ordinates,* as shown on Figure 7. By way of illustration, this diagram or plot shows forty records plotted this way, those cited above being marked with the record number, for identification. Through the spots or points thus plotted, fair curves are shown drawn for each *class,* which will thus represent the *average* result for all the records plotted. The greater the number of records of the same character, the better the curve will be for estimating purposes, or for using the curve as a temporary standard.

It may be well to explain briefly how to draw a fair or representative curve through a series of points or observations. A curve can be drawn free hand fairly closely, as to FORM of curve,—and a smooth curve drawn in later.

First mark representative spots along the page, as shown marked thus * such spots to be approximately the mean, or "center of gravity," of all the observations or points in its vicinity. Through these representative or mean spots, draw a smooth curve which will be of the proper form, but which may be too high or too low on the page. In order to determine this fact, simply see whether the sum of the distances of all points which are above our tentative curve equals the sum of the distances of all points below the curve, by measuring off in succession the distances on a strip of paper. If these sums are not the same (which they are not likely to be), divide the difference of the sums by the total number of points or observations, and the result or

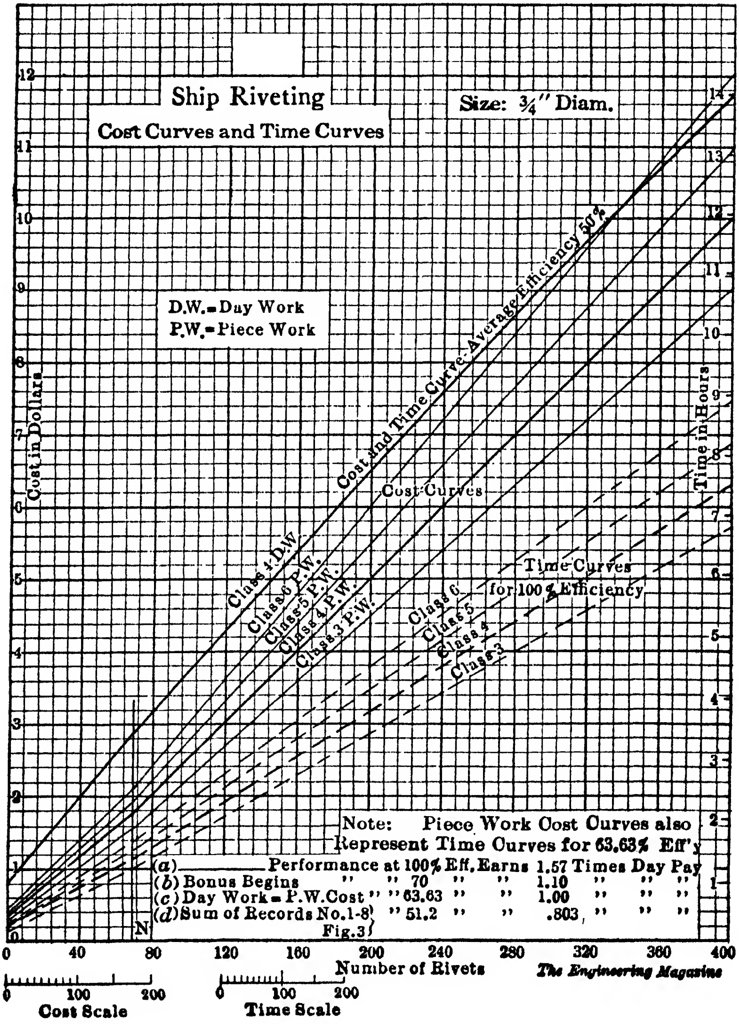

Ship Riveting
Cost Curves and Time Curves
Size: ¾" Diam.
D.W.=Day Work
P.W.=Piece Work
Cost in Dollars
Time in Hours
Cost and Time Curve: Average Efficiency 50%
Cost Curves
Class 1 D.W.
Class 6 P.W.
Class 5 P.W.
Class 4 P.W.
Class 3 P.W.
Time Curves for 100% Efficiency
Class 6
Class 5
Class 4
Class 3
Note: Piece Work Cost Curves also Represent Time Curves for 63.63% Eff'y
(a) Performance at 100% Eff. Earns 1.57 Times Day Pay
(b) Bonus Begins " " 70 " " 1.10 " " "
(c) Day Work = P.W. Cost " " 63.63 " " 1.00 " " "
(d) Sum of Records No. 1-8 Fig. 3 " 51.2 " " .803 " " "
N
0 40 80 120 160 200 240 280 320 360 400
Number of Rivets
The Engineering Magazine
0 100 200
Cost Scale
0 100 200
Time Scale

Figure (8).

quotient will represent the distance which our tentative curve has to be moved bodily up or down on the page.

We now see that the number of units for "scattered work"—which comprises a very large proportion of repair work, and which incidentally costs so much money—has a very decided bearing on unit costs, and on total costs; which we started out to observe at the very beginning of our discussion. This fact is well known by all who have stopped to think of it; certainly by all who have tried to compare unit costs for different quantities or volumes of work; yet it is frequently ignored by good estimators, and is seldom made the subject of mathematical inquiry and investigation by even the best of estimators.

In plotting miscellaneous operations in this manner we will notice wide variations from the average curve drawn; it would be profitable to look into the reasons therefor where practicable. If our classifications were exact or perfect (which we cannot expect right away)—and if we took only the records for one workman, and if we also observed the workman carefully at each performance—as to time spent in preparation, moving tools or position, etc.—then we would not only expect our points to be more uniform and regular, but we would also have, by our independent observations, the exact reasons for any variation.

The records for riveting here plotted are more regular than we will usually get for miscellaneous operations, as they represent the continuous work of a single gang under similar working conditions. Although the usual method in manufacturing work for plotting records and for estimating efficiency is on the basis of the number of *hours* of work rather than the *cost,* yet in miscellaneous operations there is an advantage in using the *cost* as the basis; in such work we may frequently use different classes or grades of labor to perform the same classes of work, and wish to determine what class of labor does the work

at the lowest total cost, not necessarily in the shortest time.

We observed at the outset that work costs more per unit for a small number of units, and up to a certain practical number of units. In manufacturing work, this limit is arbitrarily fixed by questions of convenience, and of accommodation of the shop toward other orders ahead. A machine cannot be operated indefinitely on one set of objects or parts, if there is other work in the shop which should be routed to this machine. It is the same in jobbing or repair work. Workmen have to be changed frequently from job to job, and from one kind of operation to another, for the reason that there are more different varieties of operations than there are workmen. Frequently many workmen have to work not only at different sub-trades, or operations, but at different recognized trades, in the ordinary parlance, as well.

As far as circumstances permit, however, and as far as proper planning and scheduling of operations will assist, it is the object of management to keep a workman or a gang continually employed at one class of operations, and at one definite operation until it is finished. Every break or interruption in the midst of an operation costs money—and our data put into the shape of curves will estimate for us how much money these breaks cost.

An interruption requires stopping and removal of tools or material, moving to another job, and "getting ready" to start thereon; that is, it is what we have called the "Preparation Cost." These estimated preparation costs for piece workers, for which allowances are made (see Appendix F, page 191), will vary with different trades, and for different conditions. The curves from recorded data show the average value of preparation cost as the ordinate at the origin, as originally stated in the discussion of general methods of plotting costs by curves or graphs.

The interruptions which come during a working period are most to be avoided. For operations which do not last a full

working period (of four hours in a plant in which eight hours is a day's work, as it is on all government work)—the unit costs vary considerably with the number of units performed, due to the relatively high cost (or time spent) for "preparation." For over a half-day's work, this cost of preparation (which is still about the same, regardless of the number of units) does not bear such a high ratio to total labor costs, and thereafter a straight unit price can be set without any large error being made as to actual values, and the error which is being made is in favor of the workman, mathematically.

The use of curves for studying cost data is by no means original with the writer. Their use was for a long time largely confined, however, to repetition manufacturing work, or to standardized operations. A very thorough discussion of their practical usefulness may be found in "The Management of Engineering Workshops," by Arthur H. Barker, B.A., B.Sc., etc., wherein he describes how the total time occupied in doing each job, taken from the time sheets, is entered in a book, classified under the various jobs, together with all particulars which have an effect on the time required to do them. He states that:

"When sufficient entries have been made in this book, they should be plotted on curves on squared paper, whose abscissae represent size in any convenient way, and whose ordinates represent time occupied. The points marked will, in almost every case, be found to vary widely, so that the curve will be a mean between them. The author has found that the points representing one man's performance usually lie on a fairly smooth curve."

He also observes that it will be found that it is better to use a large sheet of paper for plotting. This will be particularly

the case for the general use of curves as advocated herein, for all sorts of miscellaneous and unstandardized operations, where the time spent on a large number of units as well as on a small number are plotted on the same curves.

For practical use for all kinds of miscellaneous work, curves will be found quite as valuable as they are for repetition work or manufacturing work, particularly for estimating purposes. They will be found to be the final judge or criterion of whether a cost record is worth keeping or not. If a cost record is not in sufficient detail to classify and plot intelligently on the same sheet with similar records, then it is not worth keeping for future use. This will be found to be a simple but invaluable test, and will serve a double purpose: First, to indicate wherein the record is incomplete, either as to character of unit, size of unit, number of units, or conditions attending the work; second, to permit the destroying of old or useless records, without fear that something useful has been thrown away. There is a great and almost uncontrollable tendency in some offices to file perfectly useless data and records.

If time cards or time sheets are used for detail cost purposes, and if these are filed by elementary classes of operations, it is not necessary to copy these data again, into a book, but the data should be plotted at once on the proper sheets of cross-section paper, if the data are worth keeping; if they cannot be plotted, the cards should be thrown away. After the data are plotted, compared to the standard curve, and the efficiency of the workman properly recorded, the card can be destroyed at the end of the pay period.

The plotting of all possible cost data serves many other very useful purposes, which space does not permit to discuss fully. This plotting can be started for almost any operation, before it has even been possible to classify the operation properly. In fact, the plotting of miscellaneous operations will assist greatly in working out a practical method of classification. Before an

operation can be classified, the *unit* must be decided upon for the abscissa: the meaning of the word "*size*" of unit must be defined; and the variable conditions of (1) Accessibility, (2) Complexity, (3) Continuity—must also be defined and each assigned its relative value or influence as to the cost of the operation. In some operations, such as riveting, these three condition factors will have about equal influence upon cost; in other operations—such as laying linoleum, tiling or decking, the relative effect of varying these conditions for different jobs can best be seen after a number of records have been plotted.

After the number of classes to use are decided upon for an operation, and the relative values of the three condition factors decided upon, tentatively, then we can begin to establish a temporary standard curve of average performance for each *class* of the particular operation, for a particular size of unit. Later we can in many cases combine several curves on one sheet, for comparison.

As more and more detailed records are plotted, and as better standards or average performance curves are established, it will be possible to begin gauging succeeding performances by the standard and to mark the relative efficiencies of workmen. A separate record should then be started for each workman, and his efficiency on every operation marked, and his average efficiency for the week or pay period marked. Although these efficiency marks will not be absolute, yet they will be comparative between workmen of the same trade.

The eight records for riveting on pages 87-89, and plotted on Figure 7, are the successive records of a riveting gang for a period of 68.6 hours. If we use the piece-rate prices as our standard, with 100 per cent efficiency representing an output earning 57 per cent over day pay, we would figure the total efficiency of this gang for the period at 51.2 per cent, as may be seen from a study of the curves on Figure 8. The efficiency is simply the ratio of time actually taken by the gang, for all the

work of the period, to the time which would have been taken by a gang which is 100 per cent efficient—that is to say, the ratio of 35.1 hours to 68.6 hours, or 51.2 per cent.

Although the usual method of estimating the efficiency of operations is by comparing the estimated time with actual time taken, yet in a plant where a piece-work system is in use or contemplated, or where estimated costs or prices are used instead of estimated hours, and particularly where operations or tasks extend over portions of two or more days—it will be simpler to estimate efficiencies by the week or period in another manner—simply multiply the ratio between estimated cost (or piece-work price) and actual cost by a *Constant,* which is easily determined. (See Figures 7 and 8.) For piece work, the amount earned determines the efficiency.

Monthly efficiency reports, summarized from the weekly or periodic reports, should be made out for workmen—for all day workers, as well as for all piece workers.

It will be found that the rating of workmen in the manner outlined will, on the average, be very fair to all, and the results will far more than repay the small amount of clerical work involved. At the same time, real and reliable estimating data will be collected in concise and convenient form; the general efficiency of the working force will increase; and the management will have at hand the accurate knowledge necessary to effect improvements in management in an intelligent manner.

A study of performance curves will show more clearly and impress upon the management more forcibly than almost any other method, the low efficiency of miscellaneous operations of short duration—and will lead to studying and investigating in a sensible and businesslike manner the underlying reasons for this low efficiency. The further study of processes and of *operating* efficiency, the elimination of wasted energy, and the determination of the one best way for every operation, is an-

other subject—a comprehensive subject beyond the scope or intent of this discussion.

In miscellaneous repair work, and in unstandardized operations in general, the efficiency of *operating,* of a day worker, may often average as high as that of a piece worker, but the efficiency of *preparation* is usually much lower. Problem: How increase the latter? Whose fault is it? Is it really the workman's fault or the management's fault? Probably the latter. How remedy? Answer: Plan and schedule work properly; and by planning is meant providing all necessary material and working equipment, so as to permit the workman to start operating the tool in the shortest practicable time. Query: Why is the piece worker so much more efficient in "preparation": i.e., getting ready and starting upon the productive operation? Answer: One reason is, that he plans ahead for himself and insists on the management's preventing probable delays, due to other trades, or to lack of material. He becomes a part of the management, whose duty is to plan, and to prevent avoidable delays and interruptions. The day worker has not the incentive to plan, is not really paid to plan ahead, and cannot be expected to do the manager's work unless suitably rewarded. That is to say, the reward which a man is offered by a gain-sharing system is mostly for cooperating with the management in following the best plan and thus preparing for the highest efficiency "at the point of the tool." There is a trite but true saying that "A man is worth just a dollar-and-a-half from his neck down." It's the use which he makes of his brains that earns him more than that.

The question of preparing to do work, as distinguished from operating, or doing what is commonly called productive work, brings us to a consideration of preparation in the largest sense—the kind of preparation which the management has to make before the workmen could produce at all. This preparation is

just as necessary to production as machine work or forge work or painting, and the cost thereof enters into the cost of production just as certainly as the operating of machine tools; but on account of the complex and diversified nature of these preparation services and expenses—they are usually kept separate from the direct labor and material costs of specific operations and jobs, and are known as incidental or overhead expenses. As they cannot be conveniently charged directly to operations or job orders—like the time of the workman can (whether he is *preparing* to do productive work or is actually *producing*), these general services are charged indirectly, by distributing them by an estimating process over all jobs, and hence they are sometimes called *indirect* charges.

Chapter 10

Estimating Overhead Expense

The total cost of production consists of direct labor, material, and incidental or overhead expense. All expenditures, of course, resolve themselves into the cost of labor and the cost of material; but in getting at the cost of a product, there are certain incidental expenses which it is not practicable nor convenient to split up into small units at the time each charge is made and apportion to each order its proper share. This distribution of expense can be made indirectly, however, against each job order, by various bookkeeping methods. There are certain items of overhead expense which pertain to each shop individually, such as supervision, upkeep and repairs, light, heat, interest on shop plant investment, insurance and depreciation. These may be called "shop expense," localized by shops and distributed over all the orders in the particular shop. There are certain other items of expense incurred in the factory or plant as a whole, which are necessary to the production in all shops—such as transportation, clerical force, upkeep of general offices, salaries of manager and superintendents, etc. These items of "general expense" may be divided up between the various shops first, and later distributed to the production orders in each shop.

The simplest and most common method of distributing both general and shop expense (which compose the overhead or indirect expense or "burden") is according to the amount of productive or direct labor charged to each production order; and most costkeeping systems distribute the overhead by shops, so that all the estimator has to do is to base his estimate for overhead expense on the percentage of direct labor which the system gives to each shop.

As far as the duties of the estimator are concerned, he is usually content with making the estimated overhead expense come fairly close to the actual charges for overhead expense, these charges being automatically determined by the cost system. But if we look at the matter from the standpoint of the management, which is anxious to have the cost system distribute overhead charges over all jobs in as logical and equitable a manner as the expense of so doing will warrant, then we must look a little more critically into the customary methods of prorating all these charges. There is no such thing as absolutely accurate costs, except for the simplest kind of organization and manufacturing; and the approach to accuracy in costs may require a more expensive cost system than can be justified by the results obtained. There have been so many able treatises written upon the various methods of calculating and distributing overhead expenses, that the reader is requested to consult some of these authorities for the exposition of the subject in detail; and to regard the brief discussion which follows as a simple attempt to present in an unconventional and graphic way the relation between total production costs and its component parts.

We have confined our estimating of direct labor costs principally to miscellaneous jobbing or repair work—work in which the elements or operations are so numerous, and the variable conditions so difficult to classify, that standardization of operations has made but little progress. Each job is practically a new proposition; and before any comparison can be made with previous jobs, we have seen that we must break up each job into its elements—into elements or operations which are similar to corresponding elements in other jobs. In no other way can we make intelligent comparisons or estimates for miscellaneous work. In manufacturing work, where standard articles are turned out in a regular way, with the sequence of operations

pretty well fixed, and with the same machines or producing units always performing the same operations, it is a comparatively simple matter to analyze the various elements of cost—both direct labor and overhead expense incidental to processes and operations. That is, it is simple compared to miscellaneous jobbing work, where the equipment is necessarily more diversified, where a smaller proportion of productive work is done by machine tools, and where a considerable portion is done by portable tools and equipment—with a still larger proportion done by handworkers outside of the shop buildings.

A great many writers upon the practical distribution of overhead expense to production orders go on the principle that the simplest method is the best, and proceed to describe the simple method of pro-rating all overhead charges on the basis of direct labor costs; by simply adding to the direct labor charges the estimated percentage thereof to cover overhead expenses. The simplest use of this method is to apply a uniform rate for the whole factory; but with several departments composing the factory or plant, the accounts for each department are usually kept separate for all expenses which can be thus localized, and a separate rate is used for each department or shop for which one foreman is responsible. This simple method has its advantages from a managerial standpoint—in placing the responsibility and control of shop expense in the hands of the shop foreman; but before accepting this system as the best for costkeeping purposes, it will be well to attack the whole problem from an entirely different angle, by first trying to determine what system of estimating overhead expense incidental to processes and operations appear to be the most nearly accurate as well as the most advantageous to the management; after that is done, in the case of any particular plant, the practical question becomes: "What system of costkeeping will approach the ideal one in value to the management, and at the

same time be simple enough for every-day application, and pay for itself?"

Costkeeping, like estimating, is simply a means to an end; they are both only adjuncts and aids to good management. Records of cost, however accurate, do not *in themselves* produce economy; it is only by the proper presentation of these records in convenient and convincing form to the executives who are responsible for costs that the executives can benefit by these records, and remedy inefficiencies pointed out by the records, through improvements in organization, in administration, and in individual processes and operations. It is better to have a few main headings for cost accounts, each with a definite and distinct meaning, than to have a mass of meaningless figures scattered through a hundred account headings, all bunched together and then arbitrarily distributed all over the cost of work, and the significance and value of individual items entirely lost. Unfortunately, in the development of systems of cost records, the purpose of such records in respect to increasing the efficiency of production have not received the attention which the mere accounting for expenditures of all kinds has received. The expert accountants have made wonderful progress in devising systems of reporting total expenditures under very logical groups; and making the books balance; whereas it is only in recent years that the managers and superintendents in general have realized the great possibilities for improving the efficiency of production which proper cost records open up.

In trying to determine the most nearly accurate system of costkeeping, and the one most advantageous toward promoting efficiency of production, we might take up one by one the principal methods in use, but this hardly seems necessary, in view of the thoroughness with which the subject has been studied and discussed by so many others, whose names have become familiar as authorities. They practically all agree (as

any one will who studies the question) that the most advantageous cost system will furnish records of costs by operations, or certainly by units which are comparable with other cost records. They practically all agree that the simplest method in use of distributing overhead expense—on the basis of direct labor charges—is far from accurate, especially in a plant with a variety of products and with diversified equipment. As stated by Prof. Diemer, "This method, while simple, is objectionable because it does not differentiate articles in the manufacture of which the more inexpensive machines of a plant are employed, from articles involving the use of very expensive machinery."

The distribution of expense on the basis of hours of productive labor is open to the same objections. A more equitable method than these, in most cases, is to charge each job so much per hour for machine time as well as for man time. The difficulty with any arbitrary basis of distribution, as expressed by Prof. W. D. Ennis, M.E., is that overhead expense does not depend *on any one measurable factor*. He analyzes the various items of overhead expense, and shows graphically the distribution of elements constituting cost, briefly as shown on page 104.

Prof. Ennis then goes on to say:

"This method of distributing surcharge is as definite, logical and complete as any system could be. The objection to it is on the ground of its complication. As a matter of fact, it is complicated to devise and first apply, but simple in its continued application after having once been inaugurated. If it is worth while to study costs at all, it is worth while to pursue the study until our knowledge is accurate. It may easily take two or three years to get a system like this in working order; it may need frequent modification and revision. Hard and fast rules cannot be laid down; and in all cases some simplification is permissible."

TOTAL COST	Direct labor Materials Direct expense	INITIAL PRIME COST	Corrected Prime Cost
	Distributed burden: Charged against labor time	Wasted time Taxes (part) Heat Depreciation (part) Light Foreman and supervisors Employers' liability insurance Rent (part), Fire insurance on buildings (part) Non-productive labor (part)	
	Distributed burden; Charged against machine time (productive machines only)	Power, boiler insurance Repairs and replacements Repair supervision Depreciation (part) Rent, taxes (part of each) Non-productive labor (part) Fire insurance on buildings (part)	
	Distributed burden: Charged against corrected prime cost (or labor cost)	Fire insurance, except on buildings Non-productive labor (part) Factory indirect expenses Selling expense Administrative expense Spoiled work Standard patterns, tools, jigs, and templates Designing and development expense	

ANALYSIS OF OVERHEAD EXPENSE (DIEMER)

On account of the distinction between the "cost of production," with which the present discussion is concerned, and the total or "selling cost," the following quotation in regard to work done by Government plants, which are mainly concerned

with the cost of production, will be used, taken from the Report by the Keep Commission dated December 29, 1906, upon the subject of "Cost Keeping in the Government Service," to draw the distinction between cost keeping and cost accounting:

"Cost keeping as a branch of accounting is a comparatively modern development, and while largely employed in the commercial world has not yet been introduced to any considerable extent in the Government service. . . . In cost keeping, expenditures of money, material, and service are analyzed according to the purpose for which they are used, and it thus becomes possible to know the cost of any given piece of work or of any operation upon a single unit, or many identical units. A cost system, if properly devised and operated, will furnish information enabling the responsible head of the organization to know where economies may be effected by introducing new arrangements in organizations or new methods in operation, to estimate more intelligently on the probable cost of future operations along similar lines. . . .

"Cost keeping is that branch of accounting which is concerned with the segregation of the various items of expense, incurred in the prosecution of a single piece of work, from among all other items of expense incurred in a general line of industry, and the setting over against the total of such segregated items the quantity of resultant work or product."

The costkeeping system advocated by the Keep Commission in 1906 has the objective clearly stated in above quotation; and our modern Cost Control methods in shipbuilding attempt to carry out that objective as follows, with slight changes:

A Cost Control system (in a shipyard) will furnish information enabling the General Manager and his Staff to know where economies can be effected, and to estimate more intelligently on the probable cost of future operations.

With this objective in mind, it has been one of the Author's ambitions, and his effort, for many years to devise and install and operate such a shipyard Cost Control system. Extracts from his article published in 1920 on this Subject, titled "Production Methods in Shipbuilding: Cost Keeping the Basis for Production Control," may be repeated here. (One yard manager said recently, "It might have been written yesterday.")

"The Cost Control System to be effective must be designed and operated to fit the organization—that is, so as to show what individual in the organization is responsible for a particular cost. It is useless to collect costs under such headings as stamps and stationery, unless one individual is responsible for all the money spent in the plant on stamps and stationery—and this individual must of course have full authority to approve or disapprove anything and everything for which he is responsible.

"It is useless to collect costs by physical divisions of a ship—and at great expense find out what Bulkhead No. 77 cost for raw material, transportation, fabricating, erecting and riveting up—if one man (in the purchasing department) is responsible for the cost of raw material; another man (in another department) for transportation; a third man responsible for fabricating in the shops; and still other men in different units of the organization responsible for erecting, riveting, etc.

"The above will be clear enough to those who have tried to dig out the reason for high costs, where shop-costs are not kept entirely separate from ship-costs; and where you have to decide between the biased opinions of the shop-men and the ship-men as to which were responsible.

"In other words, a well-designed Cost Control System eliminates argument between partisan supervisors, eliminates personal opinions, and relies only upon properly recorded figures and established facts."

The article goes on to say that a good Cost Control system deals with "the methods of comparing physical progress in both hull and machinery with the Labor Expenditures, thereby determining the weekly efficiency of each foreman and trade on each Ship under construction, supplemented by methods of graphic control of production and costs."

Some of the main points for shipyards to consider were listed as follows in 1920—and they are still listed in 1943.

1) The distinction and vital difference between Cost Keeping (or cost analysis and control) and Cost Accounting or Financial Accounting. 2) The correct principle of designing a cost system—by organization units, and by operations. 3) Value of graphic presentation. 4) The Merit System—paying or rewarding every man according to his merit as a producer, possible only by a cost system with individual records of accomplishment: the yardstick for measuring merit. 5) The cost system an aid to *standard practice*—as it shows plainly by comparison the results before and after adopting the best practice or method for various operations. 6) The cost system an aid to Material Control: showing how opposition to a well-designed material control system was gradually overcome because the results were advertised by the graphic methods. 7) The cost system an aid to Standard Sequence—not only by comparing total results per ship, but by specifically preventing erection out of sequence, day by day, as bad practice was penalized in the weekly reports of progress and efficiency. 8) Method of presenting detail figures of production daily—calling attention in such a specific way to individual performances of workmen that they at once got the attention of the foreman and led to improvements. 9) Details of Hog Island Cost System—showing how the ship is subdivided into cost groups—one man being responsible for each group; how the different elements were "weighted" and the weekly percentages of completion published —comparing actual costs with standard costs at every stage.

THE COST ENGINEER'S JOB

The design of a good Cost Keeping and Cost Control system requires an intimate technical knowledge of the business, as well as executive experience in handling labor and organizing by departments, functions and operations; also a knowledge and experience in estimating by operations and units of work. It is an engineering job, but the cost engineer in charge should of course design his system of accounts and the machinery for collecting production records and data in such a manner that the Treasurer's office can then design the financial accounting system accordingly, for the two must be in harmony throughout.

The organization of a Production Control and Cost Control system in a shipyard is no easy task; a great deal of prejudice has to be overcome and, being a staff job, it is only by the unqualified backing all the way up to the top that the best results can be obtained. At Hog Island Shipyard, the Author was fortunate enough to have such backing, reporting directly to the President; and organized what was called the "Division of Standards," which performed the various staff functions. The head of each of the eight main divisions of the shipyard reported directly to the President, there being no title of General Manager. This type of organization, of course, requires that the heads of Hull and Machinery Divisions, respectively, work without friction and in close harmony; and the logical way to do so is by launching ships in a *standard condition,* just as would be done if the ways and outfitting basin were miles apart.

PRODUCTION PUBLICITY PAYS

At the time we started the Hog Island weekly cost reports and other charts, copies going to the superintendent's offices for distribution, there were with us many "old-timers" in the shipbuilding game who knew how to build ships, but who had

never seen any such reports and were at first inclined to regard them lightly. It was not very long, however, before they began to study them and take an interest in them and profit by them. It used to be a great and solemn secret, this matter of "cost" in a shipyard. All cost records were locked up in the sacred vault, and as for letting a foreman know what his costs were, that was unthinkable, unspeakable. Of course, if his costs turned out excessive, he was properly jumped on, but that was after the job was all done. It is hard to figure out how a man can be held responsible for his costs if he did not know right along how much he had spent and how much of the job had been done.

PROBLEMS IN ANALYSIS OF EXPENSE

In a method of cost keeping which makes use of the machine-hour rate, the usual practice of estimating this rate is on the basis of the probable number of hours the particular machine will be in operation for the ensuing year, and dividing the estimated annual expense incident to the machine by this number of hours. If the estimates are accurate, the total expense will ultimately go against the cost of production. A modification of the usual machine-hour rate has been advanced by Mr. A. Hamilton Church, which appears to the writer to separate the actual cost of *production* from the total cost or expenditure in a most logical manner. He proposes to introduce a supplementary machine rate, in which will be included the expenses incident to each producing unit when it is idle; and to keep this cost due to unemployment of producing units separate from prime costs, because it is not really incident to production, but incident to upkeep and maintenance of idle machines. Every producing unit or machine in the plant is given an estimated hourly rate, based upon the plant running at full capacity, so that when the plant does run at capacity all the overhead expenses of the plant will be absorbed in, or go into, the cost of

production. If, for any reason, the volume of work fluctuates, the hourly rate remains the same for charging the services of a producing unit to the work it is engaged upon; and the unabsorbed incidental expenses which are due to the state of trade and to machines being idle, are for wasted time for which the production centers are not responsible, and they may be called "establishment charges." They are not due to production but to non-production.

In speaking of Mr. Church's "Production Factor" method, Prof. Kimball says:

"Any claims of refined accuracy in this, or any other method of distributing expense, must (therefore) be taken with caution. Nevertheless, the machine rate offers a more logical method of solving this problem than any other. It will probably be some time before an extended use of the refined method outlined by Mr. Church is realized; but a machine rate for classes or groups of machines can be readily applied, and is, in fact, in common use; and there is no doubt but that this method in connection with the supplementary rate offers the best solution of the problem for most plants of diversified equipment."

It should be borne in mind that a cost system for any plant must be adapted to the scheme of organization upon which it rests. No uniform system is possible for organizations of different kinds. It may even be necessary in some plants to sacrifice some valuable features of costkeeping to bookkeeping features; but if we are looking for the system which will be ideal for a jobbing or repair plant, where the only elements of jobs which can be compared as to costs are *operations*, it is evident that the only kind of costs which will be valuable as comparative data is the cost of *operations*. If total direct labor

costs of job orders cannot be intelligently compared, evidently it is useless to add to these costs an arbitrary overhead expense and expect to benefit by it; the only *total* costs which can be intelligently and usefully compared in such cases are the costs of *operations*. Of course there will be some jobs even in a repair plant where total costs of *jobs* are comparable with other jobs; the data for figuring the proper overhead expense thereof should be at hand. It becomes a puzzling problem how far to go in the matter of pro-rating overhead expenses to job orders, in order to get correct total costs when they will be of some use, but at the same time to avoid collecting a lot of useless data on so many jobs, which will probably never occur again.

This brings us to a consideration of the practical use to make of records of overhead charges, aside from pro-rating them to individual job orders; and of estimating what these charges should be for any shop or for any group of producing units, or even for a particular producing unit. It is just as important to keep track of expenditures for upkeep of buildings, machine tools, portable power tools, hand tools and equipment, etc., as it is to keep track of direct charges for labor or material. It is also necessary to be able to judge of the probable effect upon the total costs of operations, whether we *distribute* the overhead charges to operations or not. Therefore it will be found worth while to figure out, in the best way we know how, the overhead charges which are incident to, or due to, standard operations; and we may find it advisable to estimate as close as we can the overhead charges due to the operation of individual producing units. A producing unit may be an expensive machine tool, with an hourly overhead cost when in operation of $1.00; or it may be a pneumatic chipping hammer, with a rate of 30 cents an hour; or it may be only a handwork unit, using no power, and with inexpensive hand tools requiring little expense for upkeep, with an hourly rate of only 10 cents, to cover supervision and the proper share of organization ex-

penses. Whatever the character of a producing unit, the overhead cost for any operation performed by that unit can be estimated fairly closely, if proper records of overhead expenses for the plant have been kept separately under a few main or most important headings; the estimate will, of course, be more accurate if individual records have been kept for each machine or other kind of producing unit, showing costs for power, upkeep and repairs, etc., for each unit. The main headings which will be used are chosen from Mr. Church's "Production Factors" and "Expense Burden," with a slight rearrangement for purposes of calling attention to the relatively high overhead expense incident to operations performed by expensive machine tools, compared to the low expense incident to operations performed by hand. In a jobbing plant, both kinds of operations more frequently come under the supervision of one foreman than they do in a manufacturing plant, and consequently when the same overhead rate is used for all the work under one foreman it is impossible from the cost records to know the true total cost of any particular operation. All the overhead expenses incident to production in a shop can be conveniently grouped under six main headings, and then by careful analysis, along the lines described by Mr. Church, the proper share of expense incident to each producing unit (or operation) can be estimated quite accurately—much more accurately than can be expected from the *automatic* estimating and distribution by any ordinary form of cost-keeping system. The main headings are given below.

Analysis of Expense by Production Factors

(1) Building and Land Factor.
   a. Interest, insurance, depreciation.
   b. Repairs, cleaning, painting.

(2) Power Charges.
   a. Electric, Pneumatic, Steam, Hydraulic—power.
   b. Lighting.
   c. Heating and ventilation.

(3) Stores-transport Factor.
- a. Storehouses—building factor.
- b. Store-keeping expense.
- c. Transportation of material.

(4) Organization Factor.
- a. Wages of time-keepers, planners, etc.
- b. Stationery and supplies.
- c. Cost-keeping department expenses.
- d. Watchmen and janitors.
- e. General offices—including building factor.

(5) Supervision.
- a. Salaries of manager and superintendents.
- b. Salaries of foremen and leading men.
- c. Cost of inspection.
- d. Shop office expenses—including building factor.
- e. Special offices—including building factor.

(6) Tools and Equipment.
- a. Interest, insurance, depreciation.
- b. Maintenance and repairs.
- c. Operating supplies—oil, waste, etc.
- d. Tool room charges.
- e. Jigs, dies, templates.

In a jobbing plant, of diversified equipment, it will be found convenient to consider a "producing unit" as the combination of men and tools necessary to perform any definite "operation"; and in order to estimate the total cost of the operation, add to the wages of the operators the "rental value" of their tools and equipment. This rental value or overhead cost incurred by the management for the benefit of producing units may be figured at so much per hour for each producing unit; it includes the carefully estimated amount of benefit that the producing unit derives from each of the main groups of expense above enumerated. There is considerable value in this method of considering the overhead expense incident to any operation as the "rental

value" of the facilities provided by the management to the operators to assist production, when we come to compare the total cost of operations which are comparable. This rental value of facilities represents the outlay by the management for "preparation" for efficient "operation" by the workmen, to enable them to turn out the largest output in a given time with the least effort. This preparation by the management is entirely analogous to what we termed "preparation" by the workmen, in discussing the direct labor costs of work; they are both incidental to production, both a legitimate and necessary part of total cost of production.

There are certain portions of this necessary preparatory work, preceding the actual operating of the tool by the workman, which is sometimes performed by the workman himself, and sometimes by the management; that is, it sometimes enters into total cost as a direct labor charge, and sometimes as an overhead charge, depending on the organization and shop methods. Examples of these functions are: handling material; providing tools, clamps, battens, etc.; grinding of tools; excessive time spent on "setting up" a job (a direct labor charge) due to lack of proper instruction or supervision (an overhead charge). Therefore the only conclusive way to compare the efficiencies of operations is by the total cost—which includes all the proper charge for direct labor (the time of workmen in "preparation" and in "operating"), plus all the proper indirect charges for "preparation" by the management. Such comparisons will explain to a great many who do not understand what overhead charges really mean, and who think a reduction in overhead charges *per se* indicates increased efficiency, that the form of organization, and the rules for charging men's time which are used, determine almost entirely whether certain important services are charged in as direct labor or are charged as overhead expense; and will also explain why total costs may be less—and the efficiency greater—in one plant with a very

high overhead charge, than in another plant which boasts of a low overhead expense.

Overhead cost should be kept as low as is consistent with efficient production, of course; but so should the cost of so-called direct labor, and the cost of material. And the only positive proof of efficient production is the sum of these three items of expense, each properly determined. If the cost of direct labor can be reduced $100 by increasing the overhead cost $50, the net saving is $50. This form of test applied to standardized "operations," or to comparable operations, should in time disclose the most efficient known method of performing those operations.

Chapter 11

Rough Estimates Their Use and Danger

Frequently it is necessary to furnish a rough or approximate estimate for purposes of general information, and in such event speed is more important than accuracy. In the case of repairs or other work for which definite specifications cannot be prepared, it is impossible to make anything but a rough estimate. Rough estimates are useful to prospective customers or to superior officials when the total funds available are limited and it is necessary to decide without delay what work shall be undertaken and what postponed or not undertaken. There is no use wasting time trying to make an accurate estimate for an item where the specifications are incomplete, for any reason, or where promptness is more important than accuracy. A rough estimate, however, should *never* be submitted as a *bid* or contract price, but only as a matter of general information, or as a basis for allotment of funds.

For new projects, or new machines or equipment, or for contemplated changes affecting plant efficiency, rough estimates may sometimes be close enough to determine if the project or changes will pay.

Since rough estimates, then, have their use, it will be wise to have at hand in convenient form general estimating data by which such estimates can be readily made. Total costs and unit costs of the kind likely to be used should be kept up to date.

The danger of getting into the habit of rough estimates is in the temptation to make rough estimates when careful and ac-

curate estimates can, and should, be made. In this case, rough estimates are a good deal worse than none at all. They serve none of the purposes for which real and accurate estimates are intended, and besides being a waste of time are misleading and are liable to cause trouble. Rough estimates in bidding may cause either the loss of a desirable contract, or may get an undesirable contract and lose money on it. Rough estimates on how much work a man can do in a day for a certain wage cause injustice and trouble, and if such estimates are still further used as a basis for a piece-work system, then trouble and discontent are almost sure to follow.

In making rough or quick estimates, when the necessity arises for this kind of estimate, data collected by the estimator in the shape of total costs will usually be used; the total cost includes direct labor and material, and the overhead cost (which may run from 15 to 100 per cent of the direct-labor cost). With the average form of management, in a plant doing general construction and repair work, the overhead or indirect percentage for work in machine shops or other metal-working shops equipped with expensive machine tools will ordinarily be from 40 to 60 per cent; with a functional form of management, where all or nearly all of the "preparatory" work is performed by special supervisors and planners, and hence is charged as indirect expense instead of as direct labor, the indirect percentage may easily be 75 to 100 per cent. For work not done by machine tools, but entirely by hand, the overhead cost is much less, as it is composed mostly of supervision and administration expense, and may be as low as 15 or 20 per cent of the labor cost.

Data for rough estimates should be kept on record cards, classified and indexed for ready reference. Costs of manufactured articles would be recorded by unit costs—that is, cost per article. Costs of new construction work would usually be recorded by the cost per ton or pound, for different types of

construction. In the case of buildings, the approximate cost is often estimated at a certain price per cubic foot of contents; this will vary greatly with different types of buildings, from 20 cents per cubic foot for cheap frame buildings, without heat or plumbing, up to 80 cents per cubic foot for fireproof office buildings. Data for estimating *repair* work are difficult to collect for *whole jobs,* as no two jobs are identical, and a more detailed analysis must be made of the job into its elements, somewhat in the manner which has been illustrated in the preceding pages. There is, however, a simple way of approximating the cost of a large repair job, if there is not sufficient time allowed for a detailed estimate; this is by estimating the cost of *material*—which can be done fairly accurately in a short time after the specifications for the repair job are prepared—and then estimating the cost of *labor* as being the cost of material multiplied by a *constant;* the constant for this method of estimating to be determined from the records and tabulated for different classes of jobs. For new steelwork —such as alterations or additions, involving no removal of old work—the constant (or factor) will be, for example, 2.0. For repair work, involving both the removal of old material and replacing with new, the factor or ratio of labor to material will be found to be two or three times as great as for additions only. There are many other rapid methods for approximate estimating, for different kinds of work, which will not be given but they can be found in reference works; and doubtless some can be devised by the ingenious estimator for his particular purposes.

Chapter 12

Developing an Estimating Section

In the old days all estimating was done directly by the foremen. That practice still exists in some shipyards, and will continue in many cases where there is no talent available (other than foremen) to make estimates. However, it is and has been a bad practice for any one to rely upon meagre records and so-called judgment *alone* in this matter of estimating. And the reason?

Such estimates are at best only skillful guesses, and no practical use can be made of them. All the valuable time spent on such estimating is practically wasted; for, without comparison with any sort of *standards,* they can never serve the real purpose of estimating. They do not assist the planning and scheduling by dates of the separate operations by Trades, so essential to economical performance of work. They do not assist in determining the relative efficiencies of individual workmen, so essential to individual efficiency. They do not assist in locating the causes of inefficiencies nor in improving conditions. It seems strange that the old methods of guessing at costs and the false ideas about proper estimating from recorded data costing too much, should still be clung to by some managers. Professor Hugo Diemer's very able discussion of management forcibly remarks on this phase of the subject as follows:

"In order to determine workmen's efficiency as craftsmen, it is necessary to have some system whereby comparative records are made of time required to do individual operations. Such systems are absolutely essential in order to bring a day-rate

system to a state of higher efficiency. When these systems are once installed, it requires but very little additional labor to take care of the payroll and statistics of a gain-sharing system."

An estimating section may consist of only one or two or may consist of a dozen, depending on the size of the plant and the character of work performed.

It makes no difference what titles you give people who plan or estimate or set tasks. The functions are all similar, and it is largely a question of finding the men naturally fitted for such duty and then training them diligently. A new man put at estimating, however good a mechanic or draftsman he may be or however ambitious or intelligent or systematic, needs instruction and guidance from the superintendent in charge. Without both guidance and encouragement he may flounder around for a year, more or less hopelessly, collecting a lot of experience and some good data, and improving his ability to "guess" what a thing will cost, but he may never become a first-class estimator. He should be given a chance, and should be taught and encouraged to benefit by the recorded experience of others. For instance, it is hard to see how a man can become a good planner or estimator (and they are both the same thing) without studying Mr. F. W. Taylor's "Shop Management," or some of the works of later investigators who have succeeded in planning work along the principles first so clearly expressed by Mr. Taylor. There should be a library of modern works on management always accessible to the estimators and planners. They should be instructed and encouraged to make up notebooks of their own—a kind of handbook—entering such data as are constantly needed for estimating. Each kind of industry and each trade requires a different set of tables and data of this kind.

Estimators should be taught that their estimates cannot pos-

sibly be more accurate than the recorded cost data warrant; and that they are simply wasting time and money by estimating costs to the nearest cent wherever there are no records in the plant that would warrant anyone being *sure* of estimating closer than a dollar.

I have seen well-intentioned, intelligent, careful, but misguided men of very good education, submit estimates to the nearest cent on a new construction job that aggregated over $200,000! Think of it! The data upon which the total estimate was based would not warrant anyone guaranteeing to come within $5,000. The very best sort of estimating data hardly ever warrants estimating closer than 5 per cent on small jobs and possibly 2 per cent on a very large volume of work, on anything but repetition manufacturing work or work which can be done piece-work. How many precious hours are wasted in needless and useless figuring to the *n*th decimal place! Every estimator (and incidentally every draftsman) should, if possible, take a course in the "Precision of Measurements," even if only enough to grasp firmly the absurdity—I was about to say asininity—of endless, needless figures which cannot possibly add to accuracy.

This important qualification for intelligent estimating—that of giving to all the elements of a problem their proper weight or valence, and not becoming so involved in small and relatively unimportant details that the main issue is obscured—is no less important to those higher up in an organization than it is to the estimators and draftsmen. There are problems connected with submitting bids or total estimates of much greater import, of much greater resultant effect on the profits and dividends, than the mere work of planning and estimating in detail the costs of individual operations, as above described. It would prolong this discussion beyond its immediate intent to attempt to discuss these important variables, from the standpoint of the superintendent who receives from the estimator of details his

data based upon past records and who adds to these probable costs of actual production the allowances for the state of the market, for the effect on the factory as a whole of obtaining new contracts and keeping the plant going at as near capacity as possible, and for many other considerations. For that reason, the discussion has been limited throughout to the work of estimating the cost of production, pure and simple. This limited definition of an estimate confines the subject matter to the kind of data which particularly concerns the detail planner and estimator.

There is one phase of the broader subject of submitting estimates and taking account of the effect of greater output upon the relative cost of overhead expenses, which even the detail estimator must not ignore. For an estimator to put down an estimate for overhead expense as a percentage of labor cost, in parrot fashion, from the records of past months, in the case of a large contract which would have the effect of reducing such a percentage very considerably—would make the final bid upon this basis very unreliable. This can be better explained by a concrete example, and although the example given is of the most general character, yet the process of analysis used applies to any specific job which may arise. It would be well for the principle involved to be understood by each planner and estimator—for it is the guiding principle, the paramount consideration, in all estimating; namely, the relation of volume of work to cost of work. The principle has been expressed graphically by curves and examples; for any shop or factory the average effect upon unit cost or total cost caused by varying the output may be worked out mathematically.

Take an example of a plant which has been laid out and equipped and organized for turning out 100 tons of finished product a month, working at maximum capacity, with a productive working force of 500 men. Suppose that under average trade conditions and state of the market, you have been able to keep the plant going at 80 per cent of capacity; but that

conditions become unsettled, and sometimes you cannot get orders enough to make your average output over 30 tons a month; occasionally you get a big order and run for a month or two at full capacity of 100 tons a month. Let us analyze the following assumed figures of the total costs of operating the plant, especially the varying ratio of overhead expense to productive labor costs; let us see the relation between volume of production to production cost, total cost, and profit. Figures given are for one month, being the average for previous records, under conditions given.

FIXED CHARGES. Such as interest, insurance, and depreciation of buildings, tools and equipment

$5,000 a month

These charges or expenses are ever present and are fairly constant; they do not vary with output nor with the number of productive employees. They amount to about one-half of the total overhead cost when the plant is operating at 40 per cent of its capacity—to about one-third the total at full capacity.

SEMI-FIXED CHARGES. Charges which are due to *operating* the plant, but which are large even with a very low output, and do not increase in proportion to the increase in output. Such as: Power, light and heat; repairs and upkeep of tools and equipment; organization expenses (see page 113), the sum of these semi-fixed or slowly variable charges may amount to 50 per cent of the productive labor charges at a very low output, the ratio decreasing until at maximum output these charges may amount to 15 per cent of the productive labor charges.

That is—at an output of 20 tons a month (plant operating at only 20 per cent of capacity), semi-fixed charges are

$2,000

At maximum output (100 tons a month), semi-fixed charges are $4,500

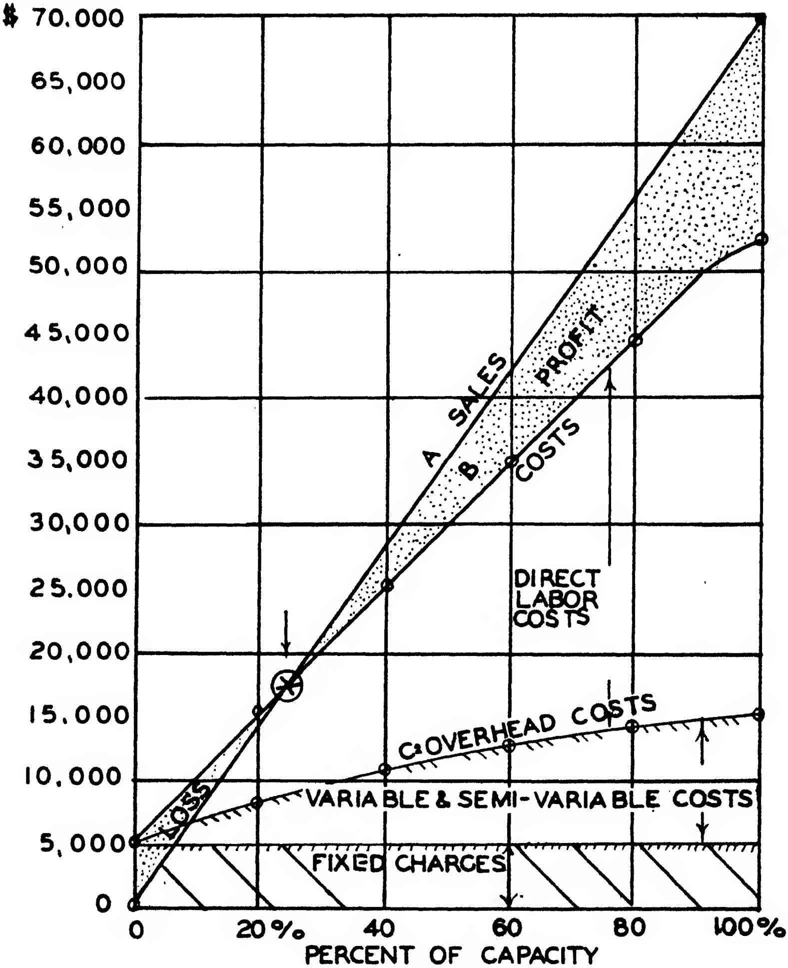

$ 70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
A SALES
PROFIT
B COSTS
DIRECT LABOR COSTS
C OVERHEAD COSTS
LOSS
VARIABLE & SEMI-VARIABLE COSTS
FIXED CHARGES
0
20%
40
60
80
100%
PERCENT OF CAPACITY

Figure (9).

Variable Charges. Charges due to operating, and which vary more nearly in proportion to variations in output, such as: Supervision (see page 113); operating supplies, etc. The sum

Tabulation of the Assumed Cost Figures Listed in Pages 123–125
Output in Tons (or per cent capacity)

	0	20	40	60	80	100
Productive labor cost	$ 0	$ 7,500	$15,000	$22,500	$30,000	$37,500
Total overhead cost	5,000	8,000	10,500	12,500	14,000	15,000
Total cost or outlay	5,000	15,500	25,500	35,000	44,000	52,500
Total cost per ton	....	775	638	583	550	525
If competition fixes the maximum selling cost at $700 a ton, maximum sales cannot exceed	....	14,000	28,000	42,000	56,000	70,000
Maximum possible profit	—5,000 loss	—1,500 loss	2,500	7,000	12,000	17,500
Notice the variation in overhead percentages	....	106	70	56	47	40
And in per cent Profit on total cost or outlay	—100 loss	—10 loss	10	20	27	33

Note: The cost of *material* is left out of account above, for the sake of simplifying the analysis, and may be assumed to be a constant amount per ton of output.

of these charges may vary from 20 per cent of the productive labor charges at a low output, to 15 per cent at maximum output.

That is—at 20 per cent of maximum output, variable charges are $1,000

And at maximum output, variable charges are $5,500

The productive labor charges are $37,500 at maximum output—with 500 productive employees, or about $375 per ton output.

Tabulating the total charges for various outputs, we see in a practical and forcible way that as far as profits are concerned,

and as far as bidding is concerned, the output compared to capacity is the most important consideration. See Table on page 125.

The general method of analysis of cost records above indicated can be used to advantage for almost any sort of costs (down to costs of output of individual machines), furnished by any sort of cost-keeping system. A closer study of the above example will make clear to the reader the essential difference between various methods of pro-rating overhead costs to productive orders. Let us look at the figures in the light of the "Production Factor" method of separating the overhead cost per hour into its elements: 1st, Cost incident to actual production by producing units. 2nd, Cost incident to idle machines and equipment—which is *waste* due to lack of work. The second element of overhead cost is the extra expense incurred in maintaining a larger plant than is required for doing all the work which can be obtained. When orders fall off to a certain point, this extra expense eats up all the profits, and one of three things must be done: (1) Get more orders; (2) operate at a loss; or (3) close up the plant.

(*Note:* The low output is assumed to be due entirely to lack of work and not to inefficient operation. That is another subject.)

Considering the above plant as a "large machine" or "producing unit," the hourly rate, or overhead cost per hour (based on maximum output conditions, and operating 200 hours a month) is seen to be $75.00. If it operates at only 40 per cent capacity, this would be equivalent in output to operating at full capacity 40 per cent of the time, or 80 hours; the other 120 hours of the month the plant is *virtually* "idle." The overhead charges due to actual production would be $6,000 for the month, 80 hours at $75.00 an hour. The remainder of the actual overhead charges, whatever they came to, would be wasted

overhead, due to maintaining a larger "capacity to produce" than was utilized. We see from our records above, or from similar records in the form of curves (overhead charges plotted upon output), that the total actual charges for overhead cost for the month were $10,500. Hence the remainder, of $4,500 (or $22.50 an hour), over and above that due to and charged to the actual production of 40 tons output, of $6,000, is "wasted." It is virtually a "loss," not a loss due to inefficient *production*, but a loss due to not operating at full capacity; and as such it can be kept separate in the statement of total cost.

Putting the presentation of the great waste due to idle equipment and tools in another manner, we may imagine the above plant to contain 200 similar machines, 80 of which are in constant operation, and 120 of which are always idle. The actual "rental value" of the 80 operating machines is only $30.00 an hour; the rental value would be $75.00 an hour for all the 200 machines in operation. That is 37½ cents per operating machine per hour. We are actually paying $10,500 rent for the use of the plant—including all overhead expenses—or $52.50 an hour, for which we get only $30.00 an hour real "rental value." The balance of $22.50 is wasted, amounting to nearly 19 cents per idle machine per hour. That is, if we operate the plant at only 40 per cent capacity, we pay 19 cents an hour for every idle hour of every machine, and 37½ cents an hour for each machine in operation.

The average estimator may not be expected to analyze cost records as a Superintendent would, in the manner illustrated, for his own amusement; but if he has been taught the use of curves by the Superintendent, in plotting expenses of all kinds as ordinates upon output or labor as abscissae he can present to the Superintendent in compact and convenient form the most important and significant facts of the whole business.

The estimating and planning department is the connecting bond between the cost returns and the producing units; it as-

sists production at the tool point on the one hand, and assists the executives to read correctly the records of production outputs and costs, on the other. Without this intelligent interpretation of records, the executives are without the eyes or ears to discover the specific causes of inefficiencies, and without the means to correct them properly, even if they were known.

In estimating the cost of work by prime elements or "operations," which, of course, means planning the work at the same time—all work can be scheduled by dates, for trades and subtrades (*operations*); thence scheduled by job orders; thence scheduled by larger groups, for example, by ships in shipwork. Schedules can also be prepared (by means of the same data) for the total work *in hand* and *ahead* for each trade, for each sub-trade, for each machine or other form of "producing unit." Orders can be properly "routed" and the progress of any item of work controlled in a systematic and efficient manner. All this has been done successfully in manufacturing work, and has been done to some extent in repair and jobbing work; the latter field is even more promising than the former, because of the greater inefficiencies which exist—supposed by many to be inherent in such work, for the reason that no one could *estimate* how long it would take (much less how long it *ought* to take) to do a specified piece of work. If the art of estimating is once mastered, the discovery and partial remedy of these inefficiencies will be possible.

Chapter 13

Estimating and Planning Combined

We have attempted to illustrate by examples, description, and references to the accepted methods of planning and estimating in manufacturing work, the application of the basic principles of logical planning and estimating to the most complex, uncertain and unstandardized kind of work in the world, namely, repairs and alterations to vessels. A few years ago, any one who claimed that such a thing as "standardizing" this kind of work, even in a limited degree, was possible, would have been laughed at as a theoretical crank. But already a start has been made, here and there, and, strange to say, always with marked success. The results have been so remarkable that only a few have acknowledged them—outside of those who brought them about. A few years hence, and many others will give the methods a fair and unprejudiced trial.

The "Variable Conditions" for miscellaneous work to be standardized we have repeatedly recognized as belonging to three groups defined as:

(1) Accessibility
(2) Complexity
(3) Continuity

These are, of course, very broad terms, and until the estimator has actually tried from recorded data, plotted and analyzed, to combine these variable conditions for an unstandardized operation into a single class, i.e., give it a classification number—he may be skeptical as to the practicability of using this method to advantage.

A little reflection may persuade the estimator to make an actual trial: By extension of the analysis of any class of opera-

tion which occurs, into its further elements of "Motions"—and making detailed time studies thereof, we will see that these three variables are but a general grouping of the broad results of more detailed study, and consequently quite possible of being made the subject of accurate estimates. We must remember (for we surely realize) that final elementary motions, or ultimate analysis of any operation into motions or even mental activities which are common to all kinds of operations and trades and to all kinds of work, are certainly possible, and that a combination of these ultimate elements make up what we commonly call an "operation." Likewise we can take any operation which occurs under various conditions of *accessibility* of work, *complexity* of material worked on, and *continuity* of performance—and by ultimate analysis into motions determine what extra motions, or what awkward motions, or what unusual fatigue, or what delays and natural interruptions, appear due to each of these various conditions. Thence we can proceed to the total or combined effect of the elements upon the total time it takes to perform a definite operation under various conditions.

This is a huge undertaking to study and reduce to rules the physical and mental laws which govern labor. Well may the leaders in Scientific Management say that the study of only *one trade* could more than occupy the lifetime of the most competent and skilled observer. On top of this, we are told and believe from experience that only one man in a hundred or so can ever become a competent and skilled observer. So what a chance the average jobbing plant has, with its fifty or a hundred different trades, and more sub-trades than employees, to solve its own problems unaided!

Chapter 14

Finishing Up a Vessel

Just as there are three periods of time in the building of a vessel, work before keel laying, work on the building ways and work after launching, so are there three somewhat corresponding physical phases or major types of work on a vessel, as follows:

(1) The hull work proper, steel work, nearly all of which is done before launching wherever practicable.

(2) The machinery installation and electrical work, including all the piping, that is to say all the work of such trades or crews as these: machinists (inside and outside the shop buildings), engine fitters, pipefitters, steam fitters, electricians.

(3) The so-called "hull outfitting trades" who finish up the "accommodations" on the vessel (which may be called the hotel features of the vessel, including the living spaces, the quarters for the officers and crew; and, for passenger vessels, also the staterooms and the public spaces).

Let us take the second and third phases of the construction, and consider the application of such management factors as planning and progress work, material control, labor control and cost control to the finishing up of a naval escort vessel, such as a destroyer escort vessel or a frigate, length over all about 300 feet or a little longer, beam around 35 feet, and making a speed of 20 to 22 knots. The total cost of the particular boat selected in the discussion to follow may run from 1½ to 2½ million dollars, depending upon where it is built, the scale of wages, whether done on "day work" or on incentive methods, and several other variables.

The main theme of this book being "how increase the output" or the "productivity per man," we will use manhours rather than dollars in discussing cost control by means of budgeting the manhours.

For the particular type of boat selected, the estimated total cost (for our purposes) corresponding to the contract price in peace times, will be the figure of two million dollars, consisting of material, labor and overhead, in the following ratios:

Material (direct)	55%	$1,100,000
Labor (direct)	27%	540,000
Overhead	18%	360,000
TOTAL	100%	$2,000,000

We will confine our discussion of "labor budgeting" to the direct labor estimate of $540,000 and use 90 cents an hour as the "average wage" in the hypothetical shipyard selected, which gives us an estimate of 600,000 manhours which has to be beaten if the contractor is to do better than just break even. That is for the total boat, start to finish; but since we are now considering only the work of finishing up the vessel, called "outfitting" in some yards, then we have to use some more figures in order to arrive at the "finishing-up" estimate to be beaten.

Therefore, we will use these figures for the manhours for this finishing-up work; that is, for the work of all trades mentioned above, which of course covers a lot of work before launching in most yards, not very much in others, depending upon their facilities and practices. Use the figure of 60 per cent of the total 600,000 manhours for this operation, and that would be 360,000 manhours allowed or estimated. Now we can go ahead and set down the application of the methods described in previous chapters to beat this "bogey" or target of 360,000 manhours for finishing up the boat.

It will be observed no doubt by shipbuilders that the figures

used just for illustration are quite on the "high side" for budgeting purposes; hence we might call the figure above of 360,000 manhours generous or liberal enough to say that it is based upon a real "PAR" for the best yard doing such shipbuilding work of perhaps 300,000 manhours. The main point is that some definite bogey or target is to be set up, each yard to use its own figures. No two yards are exactly alike in facilities, organization, personnel or methods. Some published data in Appendix E will show the wide differences in results for several yards, in manhours on cargo vessels. If similar figures could be published for ocean liners or for large Naval craft (cruisers or even destroyers) the wide differences between the best yards (most experienced and best managed) and the worst yards might be even wider than for simple cargo vessels or for tankers. The biggest differences would probably be in the so-called "outfitting work" or the "finishing-up work" which is the subject of this section of this book.

In describing the practical application of the use of our management factors to this finishing-up work on the type of vessel selected for the present purpose, it seems advisable to put down the main factors which must all be "tied in together" in the description, namely:

(a) Planning and Progress work, Planning for Material and for Labor.

(b) Material control: meaning much more than buying materials; meaning the combination of all the "functions" of all staff departments having to do with the procurement of materials, as well as the storage of materials and the distribution of materials to the work centers, whether in the shops, out on the ground or put aboard the vessels, all ready to erect or install. See Chapter 4.

(c) Labor control: this generic term embraces all the several and very important functions that concern labor; the employ-

ment of labor, the training of labor, the assignments to jobs by the foremen, etc.

(d) Cost control: this means that the costs must be "controlled" if the target or bogey of 360,000 manhours for a boat is to be met or beaten. It is a broad and embracing term; it begins with a costkeeping system, in which the costs (both in hours and in dollars) are collected and recorded in such a way that each head of department gets his records (especially of manhours) every week or every two weeks. It also means that these weekly reports by the cost department, which should reach the general foremen and the foremen promptly, should have on them the progress of the work under each main heading of Departments or Crews or Trades. That is to say, in the case of direct labor hours, the "per cent done" should be entered on these weekly cost reports by manhours, so that each responsible operative executive (Superintendents, General Foremen and Foremen) will know two things, very soon after the payroll for the week is made out. These two essential things which these executives must know (if they are to be held responsible for costs) are simple:

1) Manhours "spent" this past week and the total hours to date.

2) The per cent done (labor) of the total work to be done on boat.

This idea will be expanded in the next few pages and made simple for any foreman to understand, by the use of simple tabulations and charts.

HOW TO ESTIMATE THE PER CENTS DONE

The methods used by various yards in this weekly estimating vary a lot in details, but not much in the basic principles. Some methods are quite complicated (to the layman) but quite accurate; some methods are very simple and not very accurate, yet some methods are not only simple but very accurate. It is

the last type (simple and fairly accurate) that will be illustrated below, for only a few Trades; then a chart will be introduced to help us in estimating where other trades stand at any week or period of the ship construction program.

The methods used in estimating the progress or per cent done on the steel hull work proper are very simple, as illustrated in Chapter 15.

When we come to the work of other Trades or Crews who do the installing of machinery, piping, electrical work and the hull outfitting, we have quite a different problem, but not a very difficult one.

We will take the most difficult operations (or work of Crews) and put down the simple scheme in successful use for an escort vessel; the same ideas can be used for an ocean liner, a tugboat, a destroyer or a cruiser or a cargo vessel.

The first thing we do is to make up a complete list of all *jobs* in each category, arranged by "Sections," where one Foreman

BOAT

SECTION B - BOILER ROOMS

JOB.	VALENCE	SEPT. 4		SEPT. 11	
		%	PTS	%	PTS
1 OIL FUEL SUCTION					
2 F & B IN BOILER ROOMS					
3 BILGE EJECTORS					
4 FEED WATER PIPING					
5 AUXILIARY STEAM					
6. BOILER BLOW-OFF & BLOW-DOWN					
7. MAIN STEAM PIPING					
8. AUXILIARY EXHAUST					
9. STEAM TO O.F TANKS					
10. HOT O.F. PIPING					
11. BOILER ROOM DRAINS					
TOTALS					

Figure (10): Pipefitter installation form.

has charge of one Section, and listed in the most desirable sequence for "starting" the various jobs.

Then we assign a "Value" or "Valence" to each *job* (relative values for labor costs or manhours), which is the estimated per cent of the *Total* manhours for the whole vessel. Then each Saturday the "Per cent Done" (or tenths done) for each job is estimated and recorded on a regular form. (*See* Figure 10.)

From then on it is simple arithmetic, multiplication, addition and division. A slide rule comes in handy, and all the calculations can be made and tabulated in about an hour a week by two people working together for *all* the Trades (or crews) on one vessel.

The main thing is the set-up on a form, with the procedure outlined in a simple manner. We will first illustrate the method for machinery installation, then for pipefitter installation.

MACHINERY INSTALLATION

For simplicity, we use only five stages for this work, and for uniformity we use the same figures for each stage for each *job,* whether installing the main engines, the main boilers, the auxiliary machinery or the steering engine. In the case selected, these figures are in use:

	Allow
1. *Land* (put aboard) the Material (engine, boiler, diesel generator, etc.)	10%
2. Line up (put in correct position)	20%
3. Bolt up (secure) ready for all connections	20%
4. Connect (make all connections to piping, etc.)	40%
5. Test (reserve this 10% until tested and passed)	10%
Total for the job	100%

Here is the form used for this purpose, and for the case selected it takes only a half hour each week for the inspector (or coordinator) to go aboard a boat and check off the progress

SEQ. NO	DESCRIPTION	VALUE	1 (28)	2 (4 SEP.)	3 (11)	4 (18)	5 (25)	6 (2)	7 (9 OCT.)	8 (16)
1	MAIN ENGINES	15								
2	STEAM GENERATORS	4				1	3	5		
3	CONDENSERS	3				5	5	5		
4	AIR PUMPS	1				5	5	5		
5	EVAPORATOR	2				5	5	5		
6	CIRCULATING PUMPS	2				5	5	5		
7	FIRE & BILGE PUMPS	1				5	5	5		
8	COMBINATION PUMP	1				5	5	5		
9	DISTILLER	1				5	5	5		
10						5	5	5		
11	SECTION "B" BOILER ROOM									
12	BOILER & MOUNTINGS	10								
13	FEED HEATERS	1				5	5	5		
14	AUX. FEED PUMPS	2				5	5	9		
15	MAIN FEED PUMPS	2				9	9	9		
16	OIL FUEL HEATING & PUMPING CIRC.	1					9	9		
17	SPONGE FILTER TANK	1				5	5	5		

Figure (11): Engine fitter installation.

on one boat; then he turns in this tally-sheet to a clerk who takes five minutes to make the calculations and give the answer to the question: "What per cent done?"

PIPEFITTER INSTALLATION

On the escort vessel selected as our "case" or example, there are 60 jobs (or main job orders) under five Foremen (who are under a General Foreman.) One Foreman is in charge of Plumbing work and also a few other jobs; he is in charge of one section of five.

The bar-graph (Figure 12) shows three things for each separate job, to wit:

(1) The schedule for each job—when to start and when to finish.

(2) The actual progress, in heavy lines.

(3) The "tenths done" at the end of each week since the job was started.

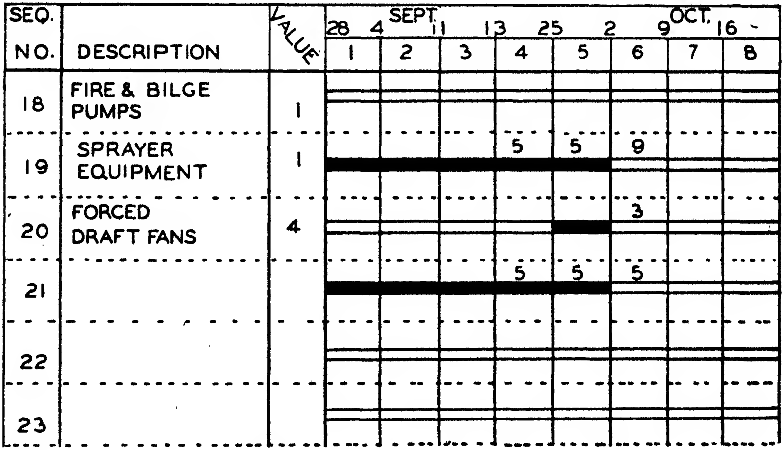


Figure (11): (*Continued*)

You will observe that this typical bar-chart is a modification and simplified form of the famous "Gantt Chart," in use for many years in repetition manufacturing and used by the well-known Industrial Engineer, Walter Clark (a pupil of both Gantt and Taylor) both in America and in Europe in his consulting work.

Now let us see what we do with these "Progress Charts."—

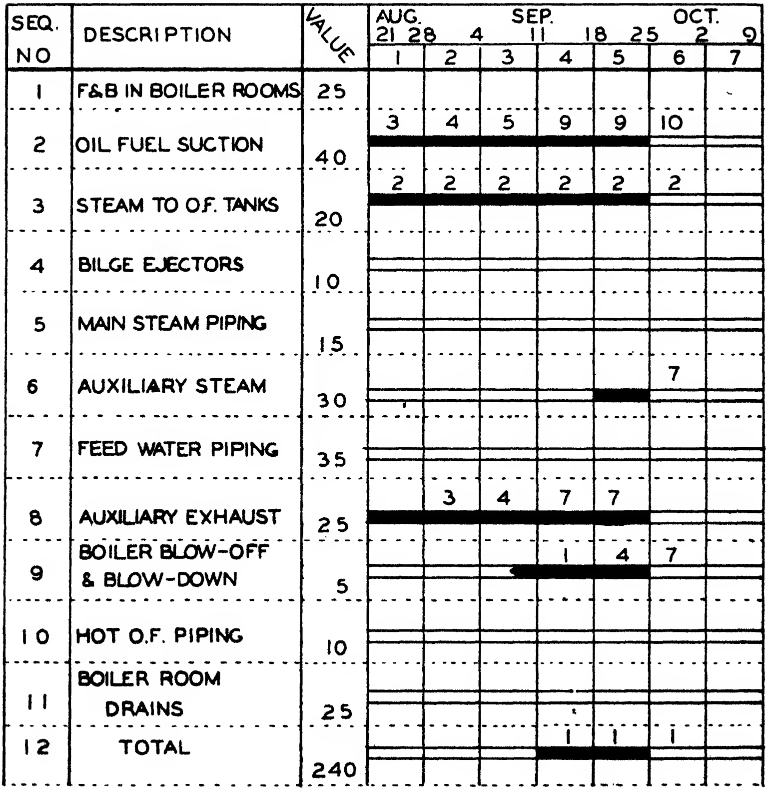


Figure (12): Pipefitter installation (boiler rooms).

Are they merely "historic records" or can they be useful for future guidance and put to work as a valuable tool of Management?

Well then, we must put on these charts the *reasons why* each job was delayed either in starting or in finishing.

The letter symbols used are as follows:

Q Questions not answered yet: Information needed as to specifications, drawings, locations on ship of materials, instructions, etc.

M Waiting for *materials,* and the items to be listed in detail.

A Alterations or changes in design or specifications.

T Trade "interferences" or waiting for other trades to finish in the spaces effected. Specify which Trades (as T1, T2, T3, etc.).

On the bar-chart you will note that at the end of each week (say Saturday noon) the progress in tenths to date is put down for each and every *job* on the vessel. Then just above this progress record you see what the scheduled Start and Finish dates are. Then you can take a glance at the schedule and at the actual lines and see whether the job is on time or behind time; it does not seem necessary to enter the desired (scheduled or estimated) progress week by week on the scheduled line. I mean not necessary in shipbuilding, although in straight and repeat manufacturing of a million articles that is, of course, usually the thing to do.

Now let us take a quick look at the simplicity and the advantages of this method.

In a shipyard of over 2000 employees, where this simple and quite accurate method is now in use, all of the records and all of the charts are kept up to date by a young man just

out of a good college (age 23) and by a young woman who also is a graduate of a good school (age 20), and that is all the staff doing all this work. Of course they belong to the Planning and Progress Department, but they might be better named as the "scorekeepers" or the folks who take the records as now given to them by others in the yard and at the end of each inning (or the end of each week) post the score on the board.

As to the interest created by this simple device of "keeping the score" and of putting it up on the board—and by the use of great big thermometers to show each week to all the people in the yard just where each vessel stands in respect to "Per cent Done," you would be surprised at the enthusiasm and the interest in the game! I've heard the men and the Foremen getting together at noon hour say: "Listen fellows, can't we make more than 8 per cent a week in our Trades on Boat 527?"

The bar-chart or another sort of progress or schedule chart is of use in keeping track of progress, either by Jobs or by Departments or Trades; but they can be made much more useful in looking ahead and pre-planning for the avoidance or prevention of the delays or "hold ups" that have occurred in the past and which must be curtailed a lot in the future if we intend to do better. The bar-charts can be put to work to tell the story each week as to just *why* any job was not started on time or finished on time; and to let the men responsible for this or that hold up get busy and correct the faults and remove the obstacles which hold up the job.

Therefore on these bar-charts (especially the simple charts shown in Figures 11 and 12) the Foremen or the General Foremen make entries in pencil alongside each job as to what the present hold up is; and then the detailed notes are presented each week (or even daily) as to the items and the pieces which are missing; this provides a clearing house for all the information needed by the producers, the workers on the boats; by the staff people; and by the top management, who have the respon-

sibility of seeing that all the people in the yard do their bit in getting the vessels finished and in service.

There are several purposes to be served by these weekly records. They enable us to forecast the probable dates of delivery of each boat and to forecast the probable final or total cost (labor cost or manhours). Also they give us a quick bird's-eye view each week of the exact state as to progress of each vessel and as to the rate or progress for the past week and for each preceding week since the first charges or costs began.

Chapter 15

Conclusions and Summary

MANUFACTURING VESSELS BY THE DOZEN

The modern miracle of building ships in less than half the time taken a few years ago is something of greatest interest.

Just a few things will be mentioned which have already been published in regard to the Liberty ships built in the United States, and then a few notes about destroyers.

In a recent number of the house organ of the Kaiser Shipyards, in Portland, Oregon, there appeared the following interesting description:

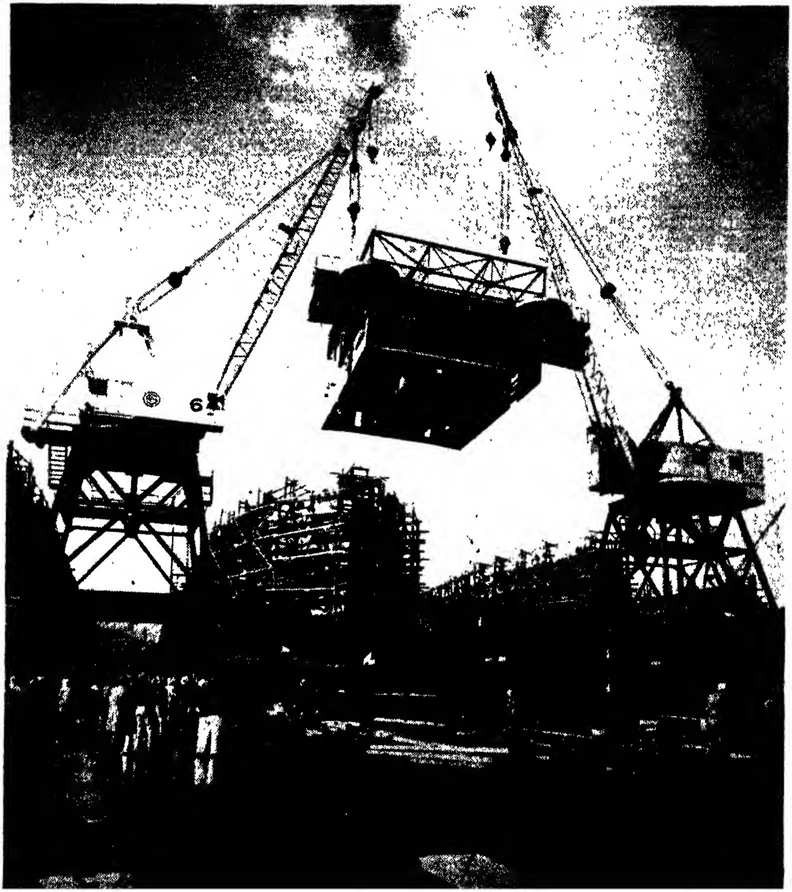
"Shipyard visitors who study the construction of Libertys are often amazed at the way the ship seems to jump together from all over the yard. Most astounding example of this modern prefabrication miracle is the deckhouse.

"With the exception of a small part on the main deck, every bit of the deckhouse is built before it ever touches the ship. It is put together on a jig weighing about 51 tons, which can be moved from way to way. The jigs are covered with plating and leveled so that they are an exact replica of the actual boat deck.

"The deckhouse itself is made up of prefabricated sections assembled in their proper places and welded together. Some of these sections are constructed in the Assembly Building and some in the area in front of the ways. First the deck bulkheads are erected, then the bridge deck plating goes into place, then another group of sections, then the hurricane or top deck, on

which will be located gun turrets, ventilators, auxiliary steering apparatus, stack, radio, antennae, safety equipment, etc.

"Finally, just about five days before launching, two giant



Courtesy of Kaiser's periodical, Plant Oregon.

Lifting 70 tons, on a Liberty ship at Oregon Shipbuilding Co.

whirly cranes lift the entire structure off the ground and set it gingerly in place on top of the ship."

The Liberty ships built at Baltimore are prefabricated in a similar manner, and the following brief quotation is given from the *New York Sunday News* of May 9, 1943:

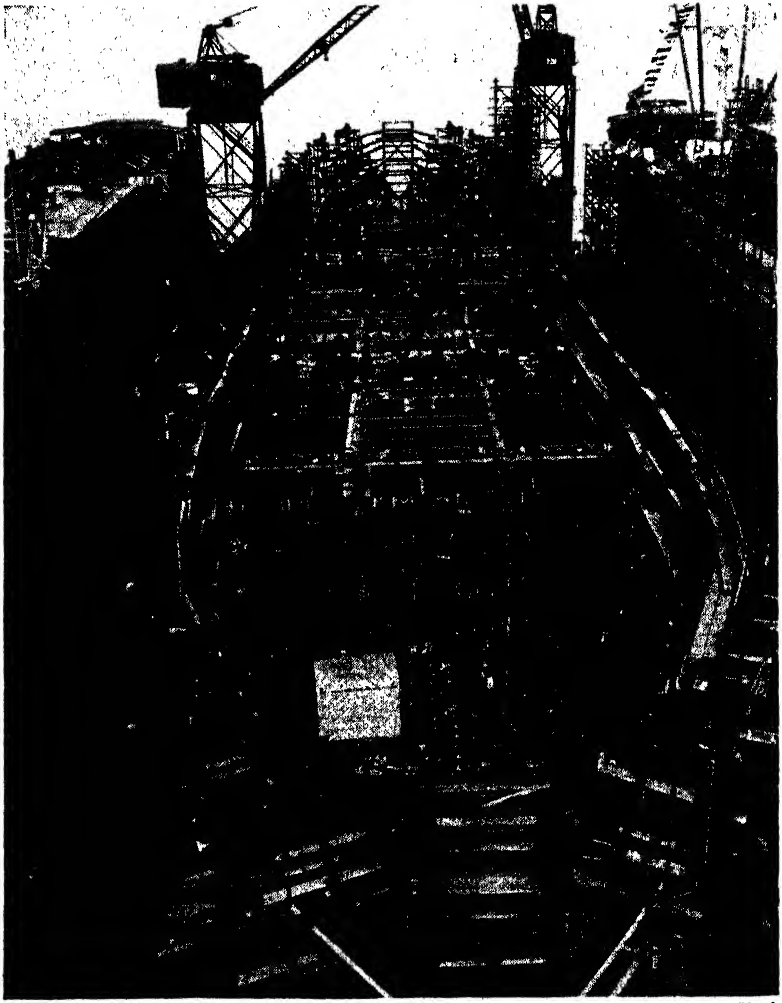
"Just 24 days after her keelplates were laid a Liberty ship slides down the ways at the Bethlehem Fairfield shipyards. She will join the bridge of ships over which supplies are being sent to United Nation forces. Before delivery, however, she will be taken to the outfitting piers for five days where ship's furnishings are installed. The ship weighs 3,200 long tons and is known as a 10,500-ton cargo vessel. The Maritime Commission program calls for 2,150 new cargo vessels by the end of 1944—a total of 39,000,000 tons. The first Liberty ship, the *Patrick Henry,* took 244 days to build in this shipyard. The time has since been cut down to 29 days."

Another shipyard building Liberty ships is the North Carolina Shipbuilding Company, in Wilmington, which has 9 building ways and is turning out Liberty type cargo ships at the rate of 9 per month.

Now, when it comes to building Naval vessels, that is a different proposition altogether.

In a publication entitled *Men O' War,* got out by the Newport News Shipbuilding and Dry Dock Company, last February, the following comment appeared:

"Operations in building large fighting ships and Liberty ships are not at all comparable, the first operation is essentially specialized shipbuilding, the second primarily mass production."



Courtesy of Daily News, New York
Copyright News Syndicate Co., Inc.

Liberty ship, building at Bethlehem-Fairfield Ship Yards, Baltimore, Md.

The best previous records for the building of Naval vessels have been so far surpassed recently that it is hard to believe such miraculous performances were possible. Just as one example, let us quote from a news item of June 12th, 1943:

"KEARNY, N.J., June 12.—The destroyer leader *Cotten* was launched at 5:27 P.M. today at the yard of the Federal Shipbuilding & Dry Dock Company, a subsidiary of the United States Steel Corporation, three weeks ahead of time. It is hoped that the ship will remain ahead of her schedule and be turned over to the Navy fully equipped, in record time.

"The record for heavy destroyers of this type—170 days from keel-laying to delivery—was set by the company March 19 last when the Navy accepted the *Dashiell*."

PRE-FABRICATION AND SUB-ASSEMBLIES

In recent years, and especially during the past two or three years, nearly all the large shipyards in the United States, and many smaller yards also, have gone more and more into Pre-fabrication and Sub-assemblies.

The *Pre* prefix means *before the keel is laid,* for steel especially, and well *before* launching for the sub-assemblies of steel units, such as deckhouses. For pipework and sheet metal work, and other classes of work, the same idea is carried out as far as practicable, and in some large yards you see acres upon acres of pre-fabricated piping—all bent to shape from wire "templets"—for vessels whose keels will not be laid for several weeks. In one yard the Author visited, 60 per cent of all the piping is fabricated (for several vessels of the same design) before the keels are laid. In another yard (a smaller yard in Canada, building escort vessels) the sheet metal work (including the ventilation trunks) is nearly 80 per cent installed before launching.

—*Official U. S. Navy Photograph.*

Destroyer Launching, Federal Shipbuilding & Dry Dock Company, Kearny, N.J.

It takes space, acres of space, and it takes big cranes (50 tons capacity and upwards) to accomplish this modern miracle in shipbuilding. And it also takes money for plant facilities, well justified when 50 vessels all alike are built in one big yard. In peacetime, conditions are different of course; but we have learned a lot in this war about "how to do the impossible" and many of the new ideas as to speed and volume will be used after we win this war.

Merchant shipbuilding is very different from Naval shipbuilding in many technical ways, and particularly in the "finishing-up" of the vessels after launching. But the pre-fabrication and pre-assembly "miracle" applies generally to all sorts and types of vessels.

THE EFFECT OF SPEED UPON COSTS

The total cost of constructing a vessel, consisting of Direct Materials, Direct Labor and Overhead, is reduced considerably by reducing the *time* of building (provided there is no change in the material and labor costs), due to the natural reduction in a large portion of the overhead costs.

This statement can be clarified by using an example, say a Naval vessel costing 5 million dollars if built in 20 months; and it may be qualified if certain staff functions are enlarged in order to gain "speed" in construction, because that will increase a portion of the overhead costs.

Let us consider a vessel built in 20 months, costing as follows:

55% =	Direct Materials		$2,750,000
25% =	Direct Labor		1,250,000
20% =	Overhead (a) Fixed Charges	$300,000	
	(b) Variable Charges	700,000	1,000,000
100% =	Total Cost		$5,000,000

Now let us estimate the total cost if the same vessel is built

in half the time, in 10 months instead of 20, but without any change in either material cost or labor cost (keeping $4,000,000 for the sum of labor plus material).

Then the difference, if any, will of course be in that part of overhead costs which consists of fixed charges (such as depreciation, certain taxes and insurance); and other overhead items not classified as "fixed" may be put in this category because they are so much a month, such as salaries of the top executives (President, General Manager, Production Manager, Chief Engineer, and other Heads of Staff Departments, as well as General Superintendent, Superintendent and others).

Therefore, we may say that these really "fixed charges" of the overhead costs are not changed or affected except by the *time* taken to build a vessel—that is, they add up to so much a month, whether it takes 20 or 10 months to build this 5 million dollar vessel.

If it takes 20 months, the figure for fixed charges is $300,000, at the rate of $15,000 a month. But if it takes only 10 months, $7,500 a month is saved by "speed," or a total of $150,000.

That means a cost of	$5,000,000
less	$ 150,000
which makes	$4,850,000

However, in order to gain *time* and cut the time in half (which has actually been done in some yards in the past three years) more *staff* work is required, a larger force in Planning and in Purchasing, in the Personnel Department and elsewhere. That would largely offset this saving of $150,000, except for the fact that the increase in *staff* work will assist the operative executives (Superintendents and Foremen) and workers to reduce costs, the Direct Labor costs especially, as well as other costs, a corresponding amount.

Therefore, it may be advisable for a yard to plan, prepare and prosecute the plans with the objective of saving time in the total construction period. *Time* is money, and in wartime sav-

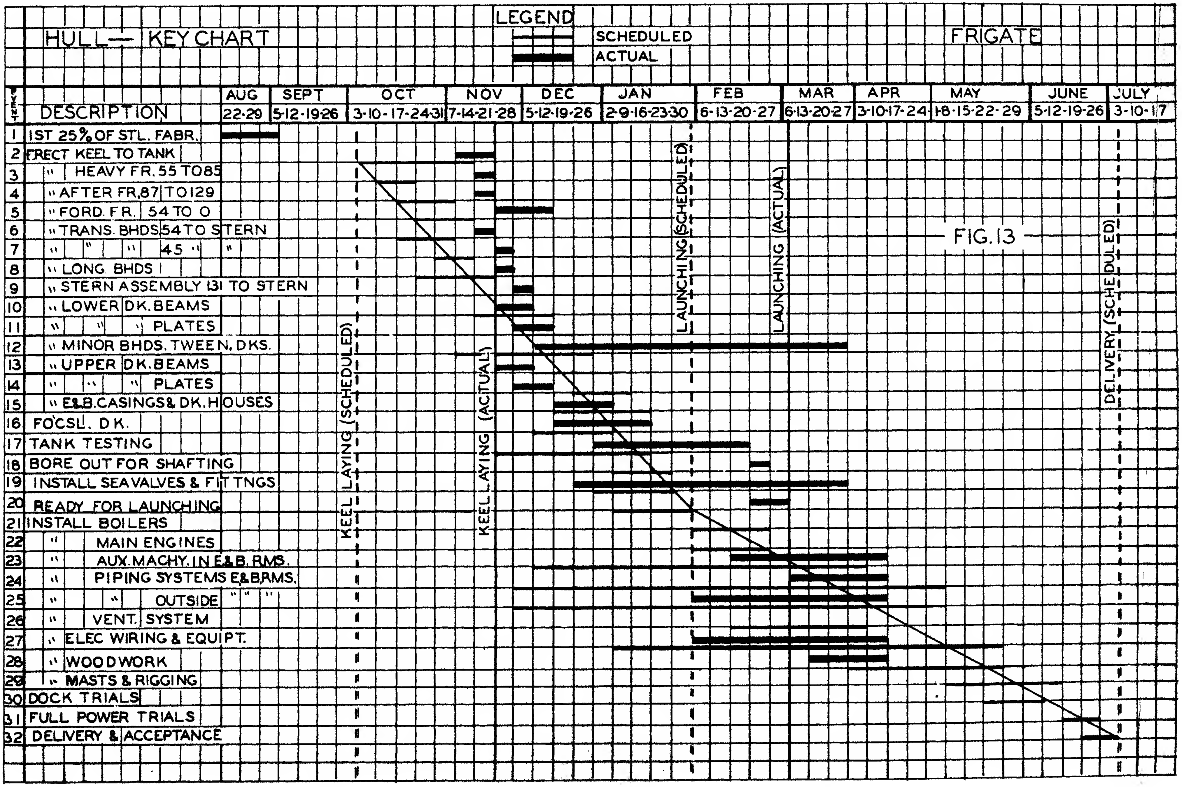
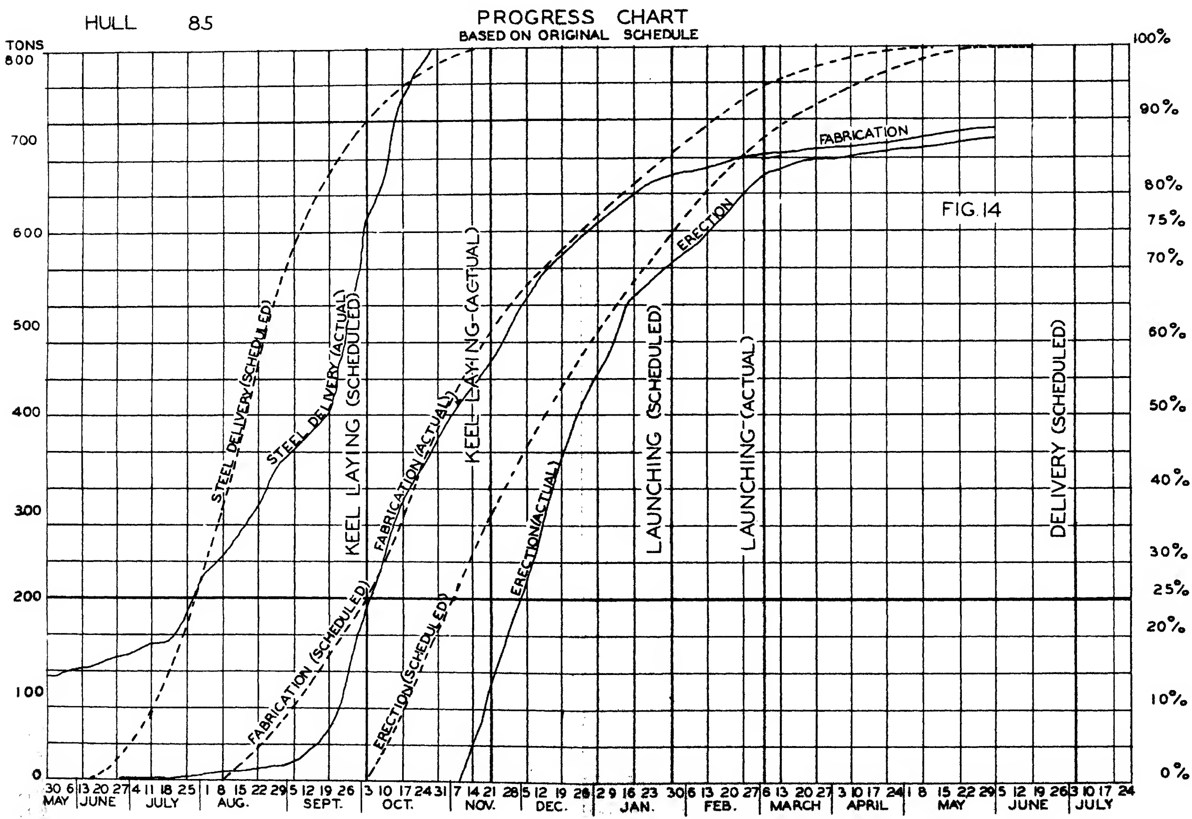

HULL — KEY CHART
LEGEND
SCHEDULED
ACTUAL
FRIGATE
ITEM
DESCRIPTION
AUG 22-29
SEPT 5-12-19-26
OCT 3-10-17-24-31
NOV 7-14-21-28
DEC 5-12-19-26
JAN 2-9-16-23-30
FEB 6-13-20-27
MAR 6-13-20-27
APR 3-10-17-24
MAY 1-8-15-22-29
JUNE 5-12-19-26
JULY 3-10-17
1 1ST 25% OF STL. FABR.
2 ERECT KEEL TO TANK
3 " HEAVY FR. 55 TO 85
4 " AFTER FR. 87 TO 129
5 " FORD. F.R. 54 TO 0
6 " TRANS. BHDS 54 TO STERN
7 " " " 45 " "
8 " LONG. BHDS
9 " STERN ASSEMBLY 131 TO STERN
10 " LOWER DK. BEAMS
11 " " " PLATES
12 " MINOR BHDS. TWEEN. DKS.
13 " UPPER DK. BEAMS
14 " " " PLATES
15 " E&B. CASINGS & DK. HOUSES
16 FO'CSL. DK.
17 TANK TESTING
18 BORE OUT FOR SHAFTING
19 INSTALL SEAVALVES & FITTNGS
20 READY FOR LAUNCHING
21 INSTALL BOILERS
22 " MAIN ENGINES
23 " AUX. MACHY. IN E&B. RMS.
24 " PIPING SYSTEMS E&B RMS.
25 " " OUTSIDE " " "
26 " VENT. SYSTEM
27 " ELEC WIRING & EQUIPT.
28 " WOODWORK
29 " MASTS & RIGGING
30 DOCK TRIALS
31 FULL POWER TRIALS
32 DELIVERY & ACCEPTANCE
KEEL LAYING (SCHEDULED)
KEEL LAYING (ACTUAL)
LAUNCHING (SCHEDULED)
LAUNCHING (ACTUAL)
DELIVERY (SCHEDULED)

FIG. 13



HULL 85
PROGRESS CHART
BASED ON ORIGINAL SCHEDULE
TONS
800
700
600
500
400
300
200
100
0
100%
90%
80%
75%
70%
60%
50%
40%
30%
25%
20%
10%
0%
STEEL DELIVERY (SCHEDULED)
STEEL DELIVERY (ACTUAL)
KEEL LAYING (SCHEDULED)
KEEL LAYING (ACTUAL)
FABRICATION (SCHEDULED)
FABRICATION (ACTUAL)
ERECTION (SCHEDULED)
ERECTION (ACTUAL)
LAUNCHING (SCHEDULED)
LAUNCHING (ACTUAL)
DELIVERY (SCHEDULED)
FABRICATION
ERECTION
30 MAY
6 13 20 27 JUNE
4 11 18 25 JULY
1 8 15 22 29 AUG.
5 12 19 26 SEPT.
3 10 17 24 31 OCT.
7 14 21 28 NOV.
5 12 19 26 DEC.
2 9 16 23 30 JAN.
6 13 20 27 FEB.
6 13 20 27 MARCH
3 10 17 24 APRIL
1 8 15 22 29 MAY
5 12 19 26 JUNE
3 10 17 24 JULY

FIG. 14

ing time is not only saving money but saving *lives,* for it also makes a shorter war, saving more and more money for the taxpayers, and thousands of human lives. Is that not a real objective, and worthy of all our efforts as builders of ships?

Speed is the word, but *haste* is not speed. In shipbuilding, unlike the digging of ditches, or the building of roads, the spaces in a vessel are confined and limited as to the number of workers who can be in a space or compartment at the same time and work effectively. Now we come to the solution of the problem: How to get *speed* and at the same time get economy? How build ships fast and without too many men on the jobs?

The answer is on record, yard after yard, and it is simply this: Good work (quality) plus good output per man or gang makes for both economy and speed. They go together.

It will amaze many people to know that a vessel can be built and completed in the shortest time by having the best record of output per hour, and by determining well ahead of time about how many men of each trade can do the work.

Even in 1918 and 1919, in the Hog Island Yard, building simple cargo vessels of 7500 tons DW, we found that in some spaces in these vessels we got 25 per cent more total rivets per day by cutting down by half the number of riveting gangs. The same goes for many other Trades—*now.*

PROGRESS CHARTS

Also see Chapter 14

Two very simple but useful forms of Progress Charts, for steel work only, are shown in Figures 13, 14 and 15.

The first (Figure 13) is a *bar-chart* (a Gantt Chart could be used, as a development) for an escort vessel 302 feet long (over-all), on which there are 32 "Events" or milestones scheduled and the progress recorded, weekly.

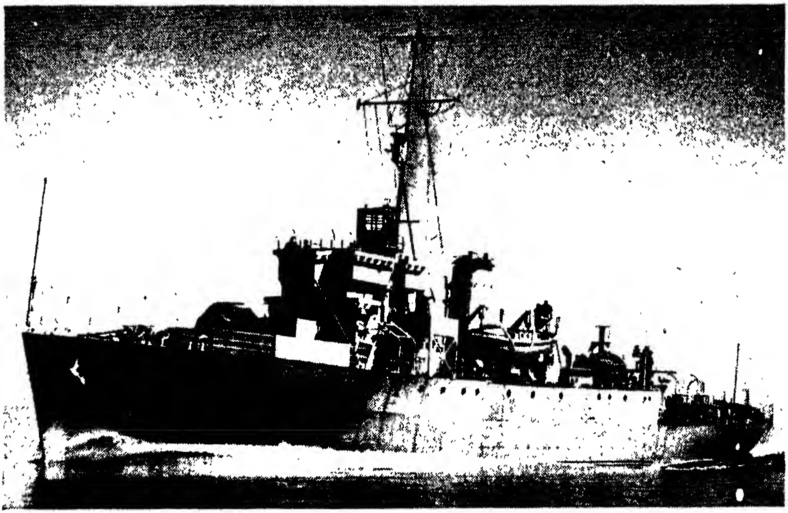
The second (Figures 14 and 15) are *trend charts* for the

the same vessel, on which the following curves appear for both scheduled and actual progress:

(a) Tons of steel received
(b) Tons of steel fabricated
(c) Tons of steel erected
(d) Per cent of total rivets driven
(e) Per cent of total welding done

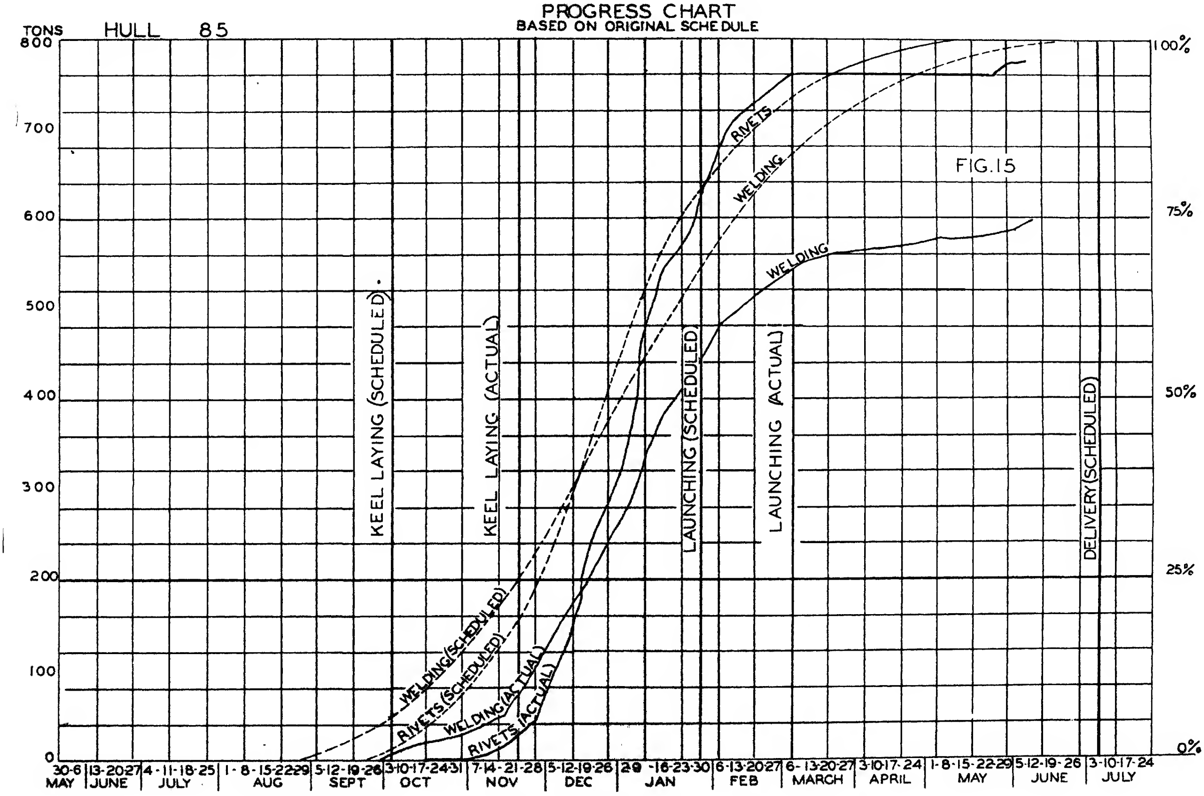
Trend charts (especially for steel work) are easily understood. Similar charts are used for other Trades than those engaged in steel work. That is, the "per cent done," or progress, is also estimated for the machinery work (shop and installation), the piping work, wood work, etc.

The trend charts are of especial value in shipbuilding—more so than in straight manufacturing, because they tell you three very important facts, at least.



—Official Royal Canadian Navy Photograph.

Minesweeper built at Toronto, Canada



PROGRESS CHART
BASED ON ORIGINAL SCHEDULE
TONS
HULL 85
800
700
600
500
400
300
200
100
0
100%
75%
50%
25%
0%
KEEL LAYING (SCHEDULED)
KEEL LAYING (ACTUAL)
LAUNCHING (SCHEDULED)
LAUNCHING (ACTUAL)
DELIVERY (SCHEDULED)
WELDING (SCHEDULED)
RIVETS (SCHEDULED)
WELDING (ACTUAL)
RIVETS (ACTUAL)
RIVETS
WELDING
WELDING
30-6 MAY
13-20-27 JUNE
4-11-18-25 JULY
1-8-15-22-29 AUG
5-12-19-26 SEPT
3-10-17-24-31 OCT
7-14-21-28 NOV
5-12-19-26 DEC
2-9-16-23-30 JAN
6-13-20-27 FEB
6-13-20-27 MARCH
3-10-17-24 APRIL
1-8-15-22-29 MAY
5-12-19-26 JUNE
3-10-17-24 JULY

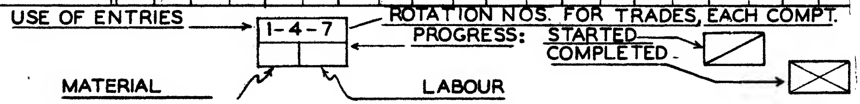
FIG. 15

ROTATION OF BOAT CREWS

COMPT.	DESCRIPTION	PLATER	WELDER	TINSMITH	ENGINE FITTER	PIPE FITTER	RIGGER	CARPENTER	ELECTRICIAN	PAINTER	
F—1	SHELTER										
F—2	C.O.'S CABIN										
F—3	C.O.'S BATHROOM										
F—4	CABIN										
F—5	GUN SUPPORT										
F—6	PASSAGEWAY										
F—7	LOBBY										

FIG. 16

LEGEND:



The trend chart (Figure 14), for example, tells you the "Time-Intervals" between major processes in two ways:

(1) Time between fabrication and erecting

(2) The "bank" of work ahead of a process (or operation)

The *trend* curve tells you about when each process will be completed, judging by the past "Rate of Progress."

This is one of the best ways to estimate or "forecast" future progress.

FINISHING UP A VESSEL BY COMPARTMENTS

It is one thing to build the hull proper of a vessel and another thing to finish up the vessel after launching. This is especially true of a Naval vessel. The outline in Figure 16 of a simple scheme, which has been used for many years in principle, has to do with an escort vessel which has only 133 separate compartments. The same idea has been used for many years in much larger Naval vessels, including cruisers and destroyers, where you might have a thousand separate compartments.

The general idea is nothing more or less than the old "Berthing System," used originally for riveting. This was started even before the last World War, and was used extensively in the larger shipyards building cargo vessels, notably the Hog Island Shipyards, near Philadelphia, and the yards at Bristol, Pa., and also by the Submarine Boat Corporation in New Jersey.

USE OF MOCK-UPS AND PERSPECTIVE DRAWINGS

The use of Mock-ups or full-size dummies in ship construction is nothing new, but the idea is in much greater use nowadays than formerly, largely on account of so many vessels of identical type and design being built in a single shipyard. The mock-up idea is used to greatest advantage in the machin-

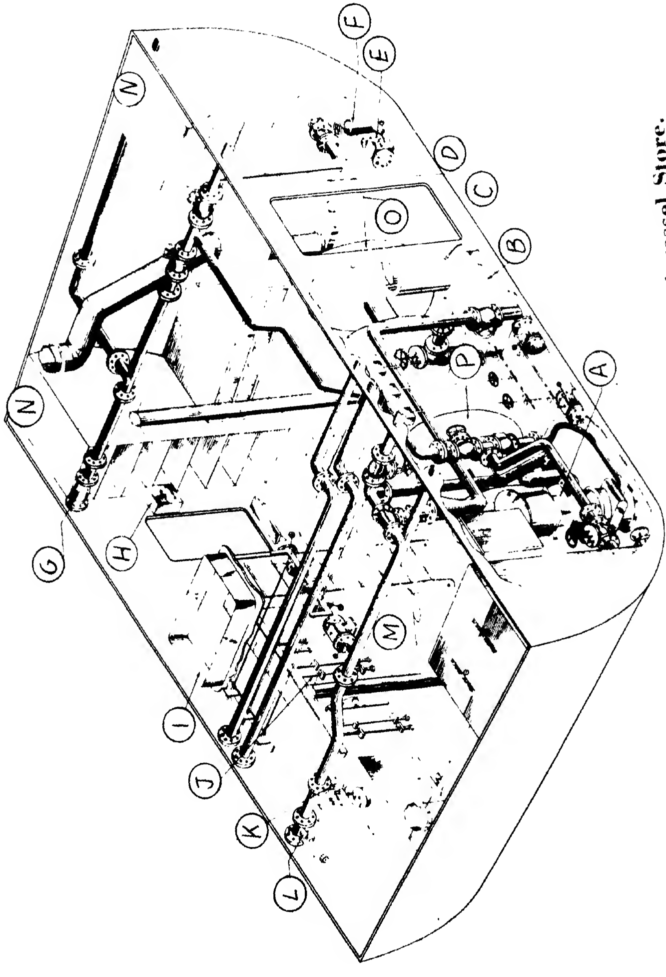


Figure (17): Isometric drawing of escort vessel Store.

ery spaces, where all the machinery and auxiliaries and piping are placed in their proper locations and also the electrical wiring, ventilation trunks and everything else shown full size.

The next best thing to a full size mock-up is to make smaller models to scale, usually ½ inch to the foot. Such a model is used in building of tankers or cargo vessels in particular, and to some extent in the building of certain types of Naval craft.

In these days, with so many new and green employees in all the shipyards, considerable use is made in many places of both isometric drawings and perspective drawings. It is so much easier for the workers and also the supervisors to install the various materials in the compartments or spaces, especially in a Naval vessel, where the spaces are very limited, by making use of these drawings in addition to the use of blueprints, of course. The teaching of blueprint reading goes on, but it takes an appreciable time for mechanics and even for some supervisors to read blueprints, and furthermore, one print only shows one class of materials, such as piping, while another shows electrical materials, and so on.

Figure 17 is an isometric drawing for the Store in an escort vessel, and Figure 18 a similar drawing of the Crew's Mess in the same vessel.

A. 1 electric pump overboard discharge
B. 1 hatch cover and coaming
C. 2 spare cable reels, port and star'd
D. 2 switches
E. 6 spare steam chests for main engines
F. 1 foamite fire extinguisher
G. 1 geared sluice valve
H. 2 coil boxes
I. 5 electric lamps
J. 2 sets spare bearing bolts for main engines
K. 1 plug receptacle
L. 1 geared sluice valve
M. 1 steel ladder
N. Rope Rack
O. Cable reel
P. Cable reel

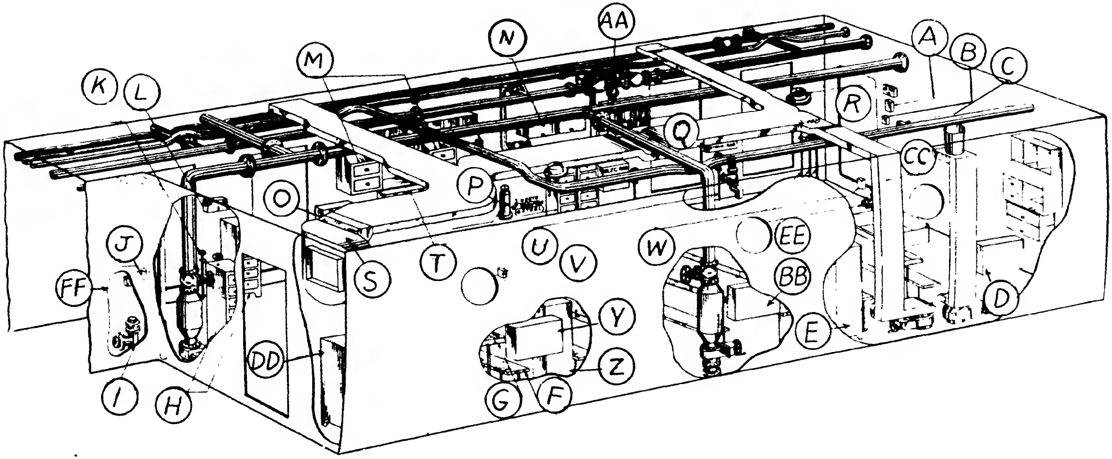


Figure (18): Isometric drawing of escort vessel Crew's Mess.

A. Fuse box
B. Switch
C. Plug
D. Steam radiator
E. Drawers, steel (6)
F. Stool (8 required)
G. Table (4 required)
H. 2 nests of drawers (6 steel)
I. Oil bunker sounding
J. Lamp
K. Oil & fuel bunker suction spindle
L. Fan starter
M. 2 mess racks
N. 2 bread lockers
O. Elec. Rad.
P. Fire extinguisher
Q. Mess rack
R. W. T. vent cover
S. Fan
T. Steam radiator
U. Plug
V. Steam shut-off to oil fuel unit
W. Oil bunker suction spindles
Y. Steam radiator
Z. Drawers (6 steel)
AA. Alarm gong
BB. Steam radiator
CC. Lamp
DD. Drawers (4 steel)
EE. Oil bunker sounding
FF. Switch

SUGGESTION SYSTEMS

Although suggestion systems have been in successful use in many shipyards, and for many years past, yet it is of interest during these war times to see what has been accomplished in this respect in the manufacturing world. Therefore, I am quoting from the condensed article by Stuart Chase, published in the May issue of the *Reader's Digest:*

"All over the country, managers are getting together with workers to increase production and hasten victory. If the habits and procedures now being formed stick after the war, industrial peace is indeed in prospect. I am making no prophecies. I am just recording an exciting beginning.

"Four workers and four managers make up the Central Production Committee. In addition there is the man who keeps the suggestion-box records—a full-time job—and the head of the publicity department, who works on committee posters.

"Next the committee gets to work on a new system for suggestion boxes and awards. A report on the results of the present system is read. In six months, some 800 suggestions have been received, and 25 per cent have been adopted. It looks like an excellent report to me, but the committee is not satisfied.

"The reward for an adopted idea has been a badge to be worn on one's coat. Now it is proposed to offer war bonds, up to $50. There would be special $100 bonds for the best suggestion each month, and for the employee submitting the largest number of adopted ideas."

CONCLUSION

In previous chapters we have briefly outlined some of the factors of Shipyard Management that were started many years ago in several yards and which have been improved greatly,

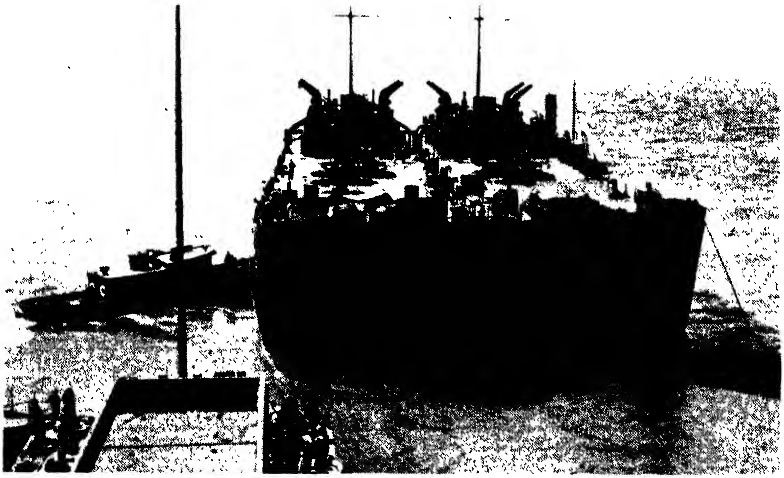
year by year, and still without departing from the fundamental principles which were in use as far back as 35 years ago.

Therefore, in this last chapter, before you start reading the Appendix, I'm going to quote from an authority who confirms to some degree some portions of this book. It is too bad that space does not permit more than a few paragraphs from the Paper presented to the Society of Naval Architects and Marine Engineers in November 1942 by David Arnott, Vice President and Chief Surveyor, American Bureau of Shipping. However, here is an extract from the Paper entitled "Some Observations on Ship Welding:"

"Our regular shipyards, which in normal peacetimes are prepared to turn out any type of ship between a barge and a battleship, had reached a high degree of efficiency in riveted construction prior to the general adoption of welding. Efficient methods of routing and handling materials and the carrying out of a maximum amount of fabrication on the ground rather than on the ways for such items as bulkheads, fantails, deck-houses, etc., was already common practice in the interests of rapid and economical construction. This is worthy of mention because a layman is apt to get the impression now-a-days that our previous shipyard methods were almost archaic and that the improvements which have taken place in the last year or two were entirely due to an influx of new ideas from dynamic personalities. As a matter of fact, the only revolutionary changes of any permanent value that have occurred are the direct result of the substitution of welding for riveting and the use of the flame torch for plate-edge preparation, cutting man-holes, etc., in lieu of shears, planing machines and manhole punches, in the use of which the work had to be brought to the machine. Certain practices are in vogue which undoubtedly facilitate the mass production of sister ships at a time when speedy delivery is the primary consideration but these are not

likely and probably not expected to survive in ordinary conditions under the stress of commercial competition.

"Production records do not just happen but are the result of careful and even meticulous planning, not the least of which is concerned with the training for a specific job of new workers, most of whom never saw a shipyard until they were hired. The educational effort involved is tremendous and reflects great credit on the instructors, most of whom were recruited from our established shipyards. Some of the handbooks on such subjects as "Shipfitting" prepared for use in trade schools are excellent both in conception and material. Under present-day conditions the time and effort spent in the preparation of detail working drawings are considerable, especially where these are augmented by the use of small-scale models and isometric sketches which are more readily comprehended by the novice. The practice at one of the Kaiser yards building large tankers is



–Official U. S. Navy Photograph.

L.S.T. landing ships, built at Newport News, Va.

to supplement the ordinary working drawings by the issue to the yard of booklets illustrating literally hundreds of different portions of the ship. Each booklet contains an isometric drawing of a specific part together with the material order and welding details, and serves the useful purpose of providing information and guidance for the workmen who are responsible for the fabrication of one particular unit. While the cost of all this preparatory work is appreciable, it is not unduly high if reduced to a per ship basis."

Appendices

A. Production Engineering

Production Engineering is a term used for the job of Engineering or "Steering" the production in a plant. Practically all of our modern papers and books on this subject refer to manufacturing; none to shipbuilding. Yet they have many things in common. Hence, you find below a few paragraphs from a recent good book (1942) called "Production Engineering" by Prof. Earle Buckingham of the Massachusetts Institute of Technology.*

* Published by John Wiley & Sons, Inc., New York, pp. 7-8.

PRODUCTION SCHEDULES AND FOLLOW-UP

"The production requirements are established by the general management, but these are usually in terms of assembled products. The requirements must be broken down, not only into the individual component parts, but also into the individual operations on each part. Schedules must be prepared for the production which will take into consideration all the other work in the plant. All schedules must be followed up, and hold-ups and conflicts with other schedules reported if predetermined delivery schedules are to be met. Among the component parts will often be found some which are common to several of the products. These are known as stock, or standard parts. They may be made in lots without reference to the specific product orders. It is necessary, in such cases, to determine the economical size of lot to manufacture and the minimum quantity of this stock part to have on hand before starting the manufacture of a new lot. The planning and control of the details are responsibilities of the production engineer. The clerical work involved may be done in some centralized clerical department, but it is the responsibility of the production engineer to see that it is done correctly and on time.

MATERIAL PROCUREMENT AND SCHEDULES

"The material required to make the product is usually ordered by the purchasing agent, but it is the responsibility of the production engineer to see that the purchasing agent has the necessary information to buy the materials required and to keep him informed of the amount needed and when it must be on hand. The amount of any specific material ordered may be based directly upon the production orders in hand, or it may be ordered for stock, as is done with standard parts, when there is any economic advantage in so doing, or if it is a critical material that may be difficult to get at short notice.

"Such conditions may change with time, and the whole material procurement problem may involve a question of policy which needs the approval of the general management. Here the detailed requirements are furnished by the production engineer, the procurement problem is stated by the purchasing agent, and the policy is established by the general management.

WAGE INCENTIVES

"The most effective wage incentive is one that helps to make the individual realize, to a large extent, that he is in business for himself. Conditions are so varied that it is doubtful if any single system of wage incentive will be the most effective for any given plant. Piece-work, bonus, group bonus, and many other types of wage incentives have their place.

"Furthermore, wage incentives alone are not enough to secure and maintain the full active support and cooperation of each individual operator. Concentration on the mechanical advances and refinements tends to push the human factor into the background, although this factor is as important as or even more important than the mechanical phase.

"The problem of wage incentives is one of policy, to be established by the general management and administered by the production engineering staff."

B. Motion and Time Study

"Motion and Time Study" is the title of a good book by Prof. Ralph M. Barnes, University of Iowa; and in the Second Edition, 1940, we find the following paragraphs in particular which apply to shipbuilding as well as to manufacturing:*

"The present trend toward increased efficiency in all kinds of work has brought about a widespread interest in motion and time study. Wherever manual work is performed there is always the problem of finding the most economical way of doing the task, and then of determining the amount of work that should be done in a given period of time. This is ordinarily accompanied by some incentive plan of wage payment. Motion and time study provides a technique that is unequalled for finding methods of greatest economy and for measuring labor accomplishment.

"The terms 'time study' and 'motion study' have been given many interpretations since *their origin.* Time study, originated by

* Published by John Wiley & Sons, Inc., New York. Ch. 6.

Taylor, was mainly used for rate setting; and motion study, developed by the Gilbreths, was largely employed for improving methods. One group saw time study only as a means of determining the size of the task that should constitute a day's work, using the stop watch as the timing device. Another group saw motion study only as an expensive and elaborate technique for determining a good method of doing work. Today the discussion of the comparative value of using either the one or the other of the two techniques has largely passed; industry has found that motion study and time study are inseparable, as their combined use in many factories and offices now demonstrates. Taking cognizance of present trends and recognizing the fact that motion study always precedes the setting of a time standard, we shall in this volume use the term 'motion and time study' as referring to this broad field.

"THE RELATION OF TIME STANDARDS TO WAGE INCENTIVES. During the past 50 years the emphasis in motion and time study application has been on the setting of time standards for use with wage incentives. Of course, motion and time study has been used for improving methods and for standardization of conditions but greatest interest and most extensive use has been for rate setting. However, the present trend is toward a more nearly balanced program. Motion study is receiving considerable attention at the present time and there is much evidence to show that this phase of motion and time study is as valuable if not more so to the manager than the use of time study for rate setting. Also, employees are more likely to react favorably to this broader program of motion and time study, particularly since motion study has as its primary object finding the easiest and most satisfactory way of doing work which usually increases output without requiring the employee to increase his effort.

"NECESSITY FOR MEASURING LABOR ACCOMPLISHMENT. Labor is an important factor in the cost of producing manufactured goods and it must be bought and paid for much like materials, supplies, and other elements which enter into the cost of production. No attempt is being made here to class labor as a commodity. In fact, there is plenty of evidence to show that the worker's mental attitude, morale, 'will to work,' and enthusiasm for the job and for the company are of real value to the management; and wages alone. however

large they may be, will not necessarily produce these desirable attributes in a working force.

"Most things of value are purchased by measure, that is, a price is paid for a number of units of a given commodity of a specified quality. For example, sugar is bought by the pound, cloth by the yard, and energy by the kilowatt-hour. When a single factor is to be measured, the unit of measurement deals only with that factor. Thus, distance may be measured by units of length and contents by units of volume. However, when two factors are involved, as in electrical energy, both time and power must be included in the unit of measurement.

"All work is largely a combination of mental and manual effort expended in a given period of time. Seldom is work entirely manual or entirely mental, although one or the other may predominate. Most factory work and much office work is largely manual in nature and it is this type of labor which is being considered in this volume.

"The results of work determine its value rather than the effort exerted. It is the operator's productivity, his accomplishment, that largely measures his worth to his employer. Since accomplishment results from the application of effort and since accomplishment is influenced by both the duration and the intensity of effort, the unit of measurement of work done must therefore include both quantity and time. Accomplishment can usually be measured most effectively in terms of quantity of work done per unit of time, that is, pieces per hour, or tons per day. Ordinarily a standard of quality is specified, and only those units that meet the quality standard are considered as finished units.

"Although much criticism has been directed at the principle of payment of labor in proportion to its productivity, there is much in favor of such a plan if properly administered. The greatest difficulty in the application of such incentives is in the determination of the standard task. The answer to the question 'What constitutes a day's work?' is very important, indeed.

"Motion and time study is the most accurate system known for measuring labor accomplishment. Although not a perfect tool, it will, if applied by well-qualified and properly trained persons, give results that are satisfactory to both the employee and to the employer."

C. Wage Incentive Methods

The subject will be presented in brief extracts from "Wage Incentive Methods" by Chas. W. Lytle.*

"In general incentives are being accepted more widely than ever as essential to high productivity and low total cost."

"*Survey of Present Use:* Most reliable data on extent to which wage incentives are now applied comes from a survey of 2,700 companies made by the National Industrial Conference Board. These companies represent all kinds and sizes of business in the United States, and employ approximately 5,000,000 workers. Of these miscellaneous companies 51.7% employing 2,655,000 workers, use wage incentives. Among them are 900 manufacturing companies ranging in size from 100 to 10,000 workers. Of these manufacturing companies 75% use wage incentives. Again breaking down to the 313 companies which furnish more specific information, 60.3% of employees who are on some incentive plan, are on piece rate plans (48.7% as individuals and 11.6% in groups). Of employees, on some incentive, 30.9% are on various premium or bonus plans (17.7% as individuals and 13.2% in groups). The remaining 8.8% of those on incentive, are on "measured" day rate; no distinction between individual and group application was reported. Counting all employees, 376,833 in the 313 manufacturing companies, 61.6% are on some form of extra-financial incentive, against 38.2% on ordinary time rates and .2% unclassified. (*See* Table 12.)

"From these analyses, it appears that COMPANY SIZE MAKES NO MATERIAL DIFFERENCE as to use of incentives. A further fact is that there appears no tendency for any few particular plans to supplant the many plans that have been put into use.

"*Broad Advantage of Incentives:* In conclusion we will reiterate the one general advantage of all regular extra-financial incentive plans. We refer to the AUTOMATIC ALIGNMENT OF EFFORT with a MINIMUM OF SUPERVISION, and most of that STRICTLY IMPERSONAL."

* Published by Ronald Press, Revised Edition, 1943. Pp. 92, 93; 187; 376, 377.

TABLE 12. EXTENT OF WAGE INCENTIVES IN THE UNITED STATES, 1940

Type of Plan Used	*Number of Employees on Plans*	*Per Cent of Those on Plans to All Employees*	
1. Ordinary time rates	143,993	38.2	
2. Individual piece rates	112,977	37.2	
3. Group piece rates	27,005		
4. Individual premium or bonus	41,031		
5. Group premium or bonus	30,613	19.0	61.6
6. "Measured" day rate	20,312	5.4	
7. Unclassified	902	.2	
Total	376,833	100.0	

Further analysis of 265 of these 300 companies shows:

Number of Companies	*Per Cent of Employees on Incentive*
14	Less than 25
15	25-49
149	50-74
72	75-89
15	90 and over

Analysis of the 300 companies as to size shows:

Number of Companies	*Number of Employees*	*Per Cent on Incentive*
30	Less than 250	55.7
64	250-499	61.8
96	500-999	65.2
47	1,000-1,999	64.0
23	2,000-2,999	62.1
27	3,000-4,999	64.5
13	5,000 and over	54.2

"*Recommendations:* The Coolidge era brought about two able and disinterested studies of wage plans which are still worthy of attention. The first in 1926 by the Manufacturers' Research Association, reprinted by the Boston Chamber of Commerce, and the second in 1928 by the Committee on Industrial Relations, National Metal Trades Association. The report of the former entitled *Principles of Wage Payment* advocates the following principles:

I. Piece Work—used loosely to mean payment of the individual on the basis of amount of production. The plans of Cheney and Dennison are mentioned by way of illustration.
   - A–Standardization of shop prior to time study.
   - B–Production rates set only on accurate time study.
   - C–Establishment of definite tasks such that good average workers' attainment of them would represent 100% efficiency.
   - D–Guarantee of minimum day work rates in all cases where failure to perform task may be due to conditions beyond operatives' control.
   - E–Establishment of definite breaking-in periods.
   - F–Provision of exact and comprehensive instruction and rate cards.
   - G–Flat reward for improved operation method followed by a new rate for same.
   - H–Use of accurate production and scrap records and wherever possible a bonus for minimum scrap.
   - I–Use of a weekly analysis sheet for executive control of labor costs.
   - J–Control of proper ratio of indirect to direct labor.
   - K–If desired, the use of an indirect labor bonus based on above ratio.

II. Group Piece Work—usual group efficiency based on points with individual rate proportion of allotment.

III. Day Work with Records.
   - A–Wherever establishment of standards cost more than expected savings from the procedure.
   - B–To be replaced by piece rate when that condition alters.

"The report specifically condemns: rate cutting, poor standardization, sharing employee savings with management, and using plans difficult of clear understanding.

"*National Metal Trades Association's Report:* This report recommends eight rules which are substantially like the ones given above.

"The report also says:

" 'Your committee, therefore:

'1. Urges members to use an incentive plan of wage payment whenever and wherever possible.

'2. Recommends that the foregoing eight rules and principles be closely adhered to.

'3. Points out the superiority of the simpler types of incentive plans, such as ordinary piece work with guaranteed day rate, over the more complex systems.

'4. Emphasizes the fact that a spirit of mutual confidence and faith based on square dealing between employees and management is essential to maximum satisfaction from all standpoints.'

"The agreement of these reports is remarkable. The standing of their organizations and the personnel of the committees gives them great weight. We find no reason for differing from them materially. As the first report uses 'piece work' to include the whole class of 'production by results' plans and as both merely condemn the more complex plans, any objection would seem to be a plea of guilty to complexity. Analysis of the numerous plans here described constantly raises the question: Are all these plans needed somewhere? The answer is obviously, No! What, then, is needed?"

* * *

"Pains Taken in Training Employees: Furthermore, Gantt went beyond Taylor in training employees to make their tasks. In writing of this, Gantt used the expression 'Habits of Industry.' He thought it was the employer's responsibility not only to provide work and tools, but to take every pains in developing habits of industry for all employees, so that after a reasonable time they could make the tasks constantly. Both Taylor and Gantt paid a separate bonus to the foreman. This made both the foremen and the men keep after the management to provide a continuous supply of work. Gantt even gave an additional bonus to the foreman when all his subordinates made their tasks. This insured every pains in the matter of training. The more complex Gantt chart for progress was later used as a basis for planning and control. The man-hour was the common denominator. The Gantt system of control can do about everything the Bedaux system can do and can do it graphically, which is even

better. The fact is, however, that the man-hour seems less flexible than the "B" and is rarely used so extensively. In his last years, Gantt spent his whole effort arousing the management rather than in arousing employees, because he felt that there was much for the former to do before they could expect employees to make further increases.

"Thus the Gantt plan is both humane and strong in its financial incentive. With the use of man record charts and proper training, the weakness of the day guarantee is minimized and the non-financial feature is given equal emphasis with the financial, making it one of the most successful plans to install wherever there have been either time rates or piece rates.

"*Standardization of the Foreman's Job:* Since some phases of foremanship may be *measured* while other phases such as cooperation may be only *graded,* it is necessary to define these terms as they apply to the foreman's job.

"Measuring: There are certain characteristics bearing upon the qualifications of a supervisor which may be definitely ascertained and measured. These characteristics concern mainly the tangible elements of his work. We can thus measure in definite units a man's attendance, the quantity and quality of production under his supervision, relative cost, and some other factors having to do with his performance and efficiency. Systematic recording of these tangible factors is what the committee means by 'measuring.'

"Grading: There are important but less tangible characteristics which cannot be definitely measured. These characteristics include character, personality, leadership, capacity for development, and other items which must be judged mainly by opinion. These characteristics are included in this report under the term 'grading.'

"With this distinction in mind, some able executive or leader of foremen should study each foreman's job. This cannot be done by merely timing. It requires joint analysis by the leader and each foreman. At best, the job can only be roughed out or outlined, but that much should be put into written form. In this way, the various duties may be weighted according to their importance and used as a basis for individual instruction. Complete cost reports, records of power consumed by equipment, facts regarding the business as a

whole, are helpful in explaining the relationship between performance and results. Frequently, a weekly or monthly class in foreman training is worth the trouble and may be given on company time. A bonus is never properly arranged without job study and is only partly successful without job training. Since increased thoughtfulness and interest are among the main purposes of an incentive, these matters must be fulfilled with particular care where foremen are concerned.

"*General Requirements for a Thoroughgoing Plan:*

"1. The plan should be guaranteed a year ahead and not changed merely because a good foreman makes more than is expected.

"2. Results should be measured or graded and the bonus paid weekly in separate envelopes. The bonuses should start at about 15% of salary and advance in proportion to responsibility, ending at 30% to 50%.

"3. The bonus must encourage: steady, but not necessarily increased production, waste and cost reduction, maintenance of quality, utilization of equipment, and assistance to employees.

"4. The bonus must not oppose: change in method or rate, transfer and interdepartmental accommodation.

"5. Operation must be fairly simple so that it can be figured with little expense and clearly demonstrated."

D. Training of Employees

This is a big subject, but the "meat in the cocoanut" is given in an article published in "Marine Age," March, 1943, and written by Prof. H. L. Seward, Yale University and Todd Shipyards Corporation. I quote a portion:

TRAINING PROGRAM AT TODD SHIPYARDS

"At each plant there is a competent and qualified Director of Training reporting in all training matters to the Consultant in the New York Office, assigned a rank comparable to other independent departments such as Personnel, Engineering, as a Superintendent

or Director. He is also responsible to the top management of the yard or plant. If he has any other duties, the training activities are his major responsibilities. All space or equipment designated as belonging to the Training Center or School is under his direction. All personnel while giving instruction or receiving instruction are under his direction. Obviously the training activities are closely interwoven with such departments as Personnel and Labor Relations and the closest of cooperation is expected, but the Training Department is a separate and distinct part of the organization with its own separate, individual authority and responsibility.

"A comprehensive training program is being established to meet the particular needs of each yard. In some yards it is integrated with production, in others it is segregated in a training center. Repair yards are subject to such variations in load that the most efficient rate of work production is not always secured because the urgency or nature of the job may require otherwise to get the best end results. All production supervisors should realize that the training program must be kept reasonably clear of interruptions made by pirating trainees temporarily to help someone over a heavy but temporary peak of work. The nature of the present day training is so highly specialized and segregated as to be but sections of former trades. No more all-round apprenticeships are possible for the duration. Our training program is designed to produce competent experts in some part-craft in a minimum of time, and the training must be given in a concentrated continuous manner.

"A few yards have had apprentice training systems for many years, but many yards have given little thought to the matter of training until recently. Each yard has its own methods of procedure, which differs from other yards for many reasons. There is a vast difference between procedures in a small yard building small wooden ships and in a large yard building large steel ships. Again, a repair yard differs from a new construction yard. Numerous methods of training have been tried, but the most satisfactory and the one which is fast becoming the most common is the one which amounts to an extension of the traditional 'breaking-in' process. This is training in the yard by yard instructors using yard tools, materials and methods of production work.

OUTSIDE SCHOOLS

"Numerous well-intentioned agencies are attempting to train workers in schools adjacent to the yards. Much good has been done, but the handicaps faced by these groups are almost insurmountable. They lack yard atmosphere. They are forced to train men in general principles to make the men adaptable to the varying demands of a number of potential employers. If employed shipyard workers are being trained in these schools, the trainees take this work at the end of the day, when often they are too tired to learn effectively. If they are training men to be shipyard workers, they are faced with the almost impossible task of acquainting the trainee with the inside of a yard from the outside.

"Attempts have been made in these outside schools to take the yard to the student by drawing instructors from the yards. This usually fails because the instructor is first a mechanic and not necessarily an instructor. Removing him from his element destroys his effectiveness. It is impractical to attempt to duplicate yard tools, materials and methods in exterior schools, if the trainees are being prepared for more than one potential employer. If only one yard is involved, the tools and materials are not available because they are needed for production work.

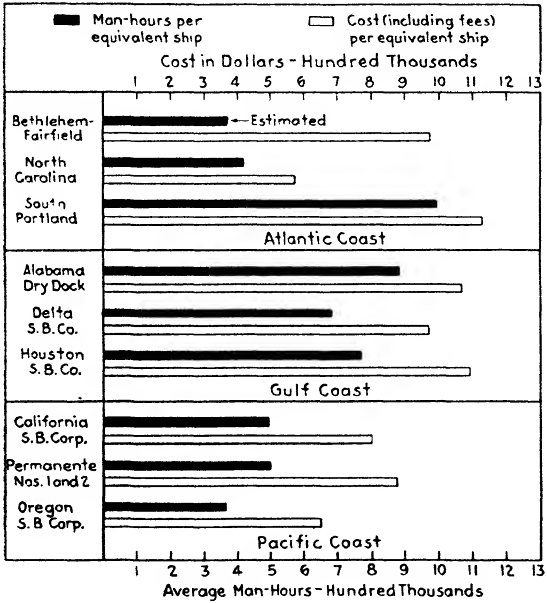
"All this leaves the final job of training to be done when the trainee reaches the yard. Some yards have a preliminary course which must be taken by every man hired in order to know his way about, to understand the general purposes and aims of the yard, how to get things and how to draw his pay."

E. Shipbuilding Performance Records

In this section we put down some figures of performance.

In the *New York Times* of June 23, 1943, appeared the following:

"Merchant ships, including tankers, are being delivered at the rate of five per day. From the first of the year through May there were delivered 711 ships having 7,142,122 deadweight tons. In all 1942



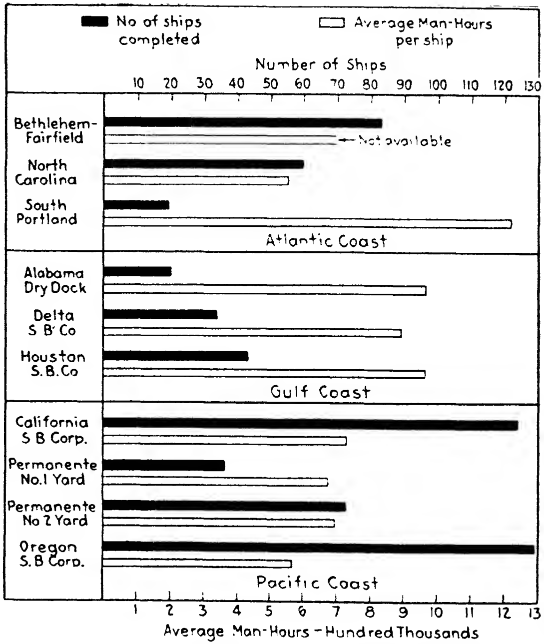


Table 1

Estimated going value and man-hour statement for Jan. 1943

Average man-hours and total number of Liberty ships completed by each builder to Jan. 31, 1943

total deliveries were only 746 vessels, having 8,090,800 deadweight tons.

"May deliveries were 175 vessels totaling 1,782,000 deadweight tons."

In Chapter 15, we have already given a few performance records. Here we put down some more detailed data which have recently been published (June 1943 issue of "Marine Engineering and Shipping Review") under the heading: "The Truman Report on Shipbuilding."

TABLE 2. ESTIMATED GOING VALUE AND MAN-HOUR STATEMENT FOR JANUARY 1943 AS SUBMITTED BY THE MARITIME COMMISSION TO THE TRUMAN COMMITTEE

Shipbuilder	*Man-hours per equivalent ship*	*Cost[1] (including fees) per equivalent ship*
Alabama Dry Dock	885,000	$1,070,000
Bethlehem-Fairfield[2]		979,000
California Shipbuilding Corp.	498,600	810,000
Delta Shipbuilding	680,000	969,000
Houston Shipbuilding	770,400	1,085,000
Marinship	1,691,000	2,474,000
North Carolina	421,000	576,000
Permanente Richmond No. 1 Permanente Richmond No. 2	501,200	875,000
Oregon Shipbuilding	371,300	657,000
South Portland Shipbuilding	996,400	1,130,000

[1] Exclusive of costs of material furnished by the Maritime Commission—about $700,000 per ship.

[2] Bethlehem-Fairfield informs the committee that "we feel certain our present costs are averaging $660,000 per ship, not including fees, with labor hours averaging 370,000 per ship."

This table should be compared with the accompanying Table 1. The following are paragraphs from the same article:

MAN-HOURS

"The production records obtained by the committee from the contractors covering the month of January 1943 and the results obtained by each yard from the date of first contract up to January 31, 1943, provide the industry an opportunity to evaluate and compare the relative efficiency of each yard. It will be observed from Table 1 covering total production that the organization with the lowest average man-hours is the North Carolina yard with a figure of 558,210, closely followed by the Oregon Shipyard with 572,397. However, the Oregon yard with 11 ways has produced 172 ships up to May 1, or 17.4 per way, compared with 89 finished by North Carolina on 9 ways, or 9.8 per way, in exactly the same period. As to the current rate, the Oregon yard states it recently delivered a Liberty ship with a total of only 362,114 man-hours, while in each of the months of March and April 18 and 17 ships were completed, a rate of 1.6 ships per way per month. The 17 ships completed in April required an average of 28.5 days from keel laying to delivery. North Carolina informed the committee it has now delivered a Liberty ship with a total of 406,635 man-hours. In each of the months of March and April 10 ships were completed, a rate of 1.1 ships per way per month.

"Data were not available covering the average man-hours for the total production by the Bethlehem-Fairfield yard, but the committee was informed that the average man-hours employed on the 16 Liberty ships completed in March was 390,000, while the current rate was approximately 370,000 man-hours per ship.

"The largest producer of Liberty ships, the California Shipbuilding Corporation, with 173 completions up to May 1 on 14 ways, a rate of 12.3 ships per way, averaged 729,415 man-hours per ship up to January 31. However, it is understood the current rate at this yard is now also under 400,000 man-hours per ship. While apparently the two Richmond yards of the Permanente Metals Corporation have not been able to produce a Liberty ship with less than 400,000 man-hours, as is the case with the aforementioned yards, it will be noticed that the average man-hours for the total ships produced is better than the rate at the California Shipbuilding Corporation. On their combined 19 ways 161 ships have been built, a rate of 8.4 per way."

F. Piecework Prices

THE SCALE OF WAGES 1914 TO 1943

The 1914 rates per day of 8 hours are given below for the principal trades in the U. S. Navy Yard, Charleston, S.C. These figures are exactly as published in the Author's book, "Estimating the Cost of Work." There were four grades of pay. The highest and lowest rates only are given here.

Trade	*Highest*	*Lowest*
Acetylene welder	$3.44	$2.80
Anglesmith	3.76	3.04
Blacksmith	3.28	2.24
Calker, wood	3.44	2.56
Calker and Chipper (iron)	3.44	2.80
Driller	2.48	1.76
Forger (heavy)	4.00	2.80
Galvanizer	3.04	2.24
Joiner (ship)	3.52	2.24
Light-metal worker	3.04	2.80
Loftsman	4.32	3.68
Molder	3.76	2.80
Painter	3.04	2.24
Plumber	4.00	2.56
Puncher and Shearer	2.56	1.76
Rigger	3.52	3.04
Riveter, Machine	3.44	2.80
Shipfitter	3.60	2.88
Shipwright	3.44	2.56
Upholsterer	3.52	2.80
Wire-worker	3.28	2.48
Laborer	1.52	1.04
Helper, General	2.00	1.28
Helper, Painter's	1.76	1.28
Helper, Rigger's	1.76	1.28
Helper, Steel-worker's	2.00	1.28
Helper, Wood-worker's	1.76	1.28
Holder-on	2.56	1.76
Boy	1.28	0.56

Before setting down the next table, of hourly rates, we should state that the Average Basic Rate for the large private yard is the rate of the workers and not their *earnings* – for piece workers *earn* much more than the hourly rate.

	Private Yard	
	1914	*1943*
Anglesmiths	.215	.860
Blacksmiths	.250	.908
Boilermakers	.242	.939
Coppersmiths	.320	.863
Drillers	.220	.821
Electricians	.280	.898
Fitters, Ship	.223	.954
Foundry	.256	.888
Hull Fittings and Plant	.250	.924
Joiners	.317	1.020
Lumber Yard	.228	.877
Machine Shop (Brass)	.277	.974
Machine Shop (Main)	.291	.899
Painters	.286	.875
Pattern Makers	.336	1.140
Plumbers	.280	.933
Power House	.223	.934
Riveters	.170	.929
Sheet Metal Workers	.252	.938
Ship Carpenters	.274	.999
Ship Riggers	.390	.972
Ship Shed	.208	.839
Steam Engineers	.276	.863
Toolmakers	.318	.926
Welders	.314	1.010
Yard Riggers	.203	.728

Average base rate for operative and material supply departments, without supervision for the year 1914: .223; for April 1943: .868.

LIST OF PRICES

The following represents extracts from "Estimating the Cost of Work" (1915), followed by later prices as published in 1929 by M. Francis Carr in his book, "Estimating the Cost of Ships."*

* Published by Theo. Gaus' Sons, Inc., New York.

The tables above will assist in estimating the difference in today's prices and putting the 1914 dollars and cents into present values.

In general, the present basic hourly wage is about four times as much as in the year 1914. In some areas it may only be three times as much.

EXTRACTS FROM "ESTIMATING THE COST OF WORK"

The prices below are intended to cover any amount of work, large or small, whether in the shops, on the ground or on ships at repair wharf or in dry dock; that is, where the distance to travel between jobs successively assigned is not great. For work at a great distance, *e.g.*, on the *Hartford, Olympia* or vessels at torpedo-boat docks, an extra allowance for any necessary travel between jobs in excess of 300 yards will be allowed at the rate of two minutes' day pay for each extra 100 yards, or fraction thereof.

All unit prices for an operation will be set strictly according to schedule and all proper allowances (if any) covered by schedule will be determined in writing and agreed to by the workman before the operation is started, under the personal direction of the Construction Officer and the Warrant Officer in direct charge of piece-work system.

AS ASSEMBLING

Coal Barges.	Ordinary frame, complete up to main deck	$1.25	each
	Truss-frame	2.00	"
	W. T. bulkhead, complete up to main deck	6.00	"

This work includes the necessary assembling, bolting, reaming, fairing, etc., for riveting of the entire frame or bulkhead. All angle clips, bounding bars, stiffeners, floors, and frames to be attached and all faying surfaces to be painted.

BO BOLTING UP

Includes taking plate as left by erecting gang and fairing and bolting tight ready for riveters. These prices include all classes of bolting up.

Coal Barges.	Shell plates, inner strake	$1.00	each
Special Prices.	Shell plates, outer strake	1.50	"
	Shell plates, bilge strake	2.50	"
Transverse bulkhead plates		0.75	"
Deck plates with seam straps		1.00	"
Deck plates without seam straps		0.75	"
Bolting up brackets		0.05	"

Bolting up clips	0.05 each
Bolting and packing bulkhead staples	1.00 "
Rider plates	0.05 "
Longitudinal girder plates	1.00 "
Bolting up B. H. on ground	3.00 "
Bolting up B. H. transverse frames, on ground	2.00 "
Transverse bulkhead; bolt and pack bounding bars	1.00 "
Bulkhead stiffeners	0.10 "

General Prices. All bolting up straight work.

	lbs., per sq. ft.				
Weight of plates up to and including	7½	15	20	30	40
Bolting up, per bolt	.01	.0125	.015	.02	.025

For plates rolled or furnaced, price and a half.

CA — Calking, Pneumatic

The price for calking will include payment for all chipping necessary to fair up edges and to make good calking, assuming the average amount chipped from the edge of any metal to be less than ¼ inch. Where a greater average amount is required, it will be paid for according to the regular chipping or cutting schedule, depending upon the amount removed in addition to the regular calking price. Calking corners of angles, whether inside or outside, and with or without dutchmen, included in straight prices for calking. Joggles over laps of plates, butt straps, etc., with all dutchmen, tapered liners, etc., included in the straight price for calking. Regular price only allowed for calking staples around watertight floors, division plates, etc. Filling pieces to be allowed extra only where required throughout length of open butt. Price and a half to be allowed for all work in tanks and double bottoms when closed in.

	Price per running ft.
Straight calking, planed or chipped	$.0120
Straight calking, not planed or chipped	.0200
Butt calking	.0250
Crooked tool work	.0250
Heel of bars	.0250
Oil tight work	.0200

CM — Cementing

Portland cement in bilges and double bottoms, and under tiling:

1. (a) For average thickness below 3 inches, per cu. yd.	$ .25
(b) For average thickness above 3 inches, per cu. yd.	.20
2. Cement under tiling, per sq. ft.	.04

CH — CHIPPING, PNEUMATIC

Trimming of edges, or surfaces, of metal will be counted as chipping when the average depth of cut is not over ⅜ in. If a greater thickness of metal than ⅜ in. is to come off, cutting prices will be used. Price and a half to be allowed for all work in tanks and double bottoms when closed in.

1. Price for straight chipping ½ cent per ⅛ inch width of cut, per running foot.

2. For circular trimming, price and a half, such as manholes and lightening holes.

CC — CHIPPING AND CALKING, PNEUMATIC

	Per 100, countersunk head rivets, and tap rivets					
Diam. of Rivets, in.	½	⅝	¾	⅞	1	1⅛
Chipping and Calking	$1.50	1.75	2.00	2.25	2.50	3.00
Calking only	1.00	1.25	1.50	1.75	2.00	2.25

Liners and scarphs, chip and calk, each $.010

CK — COUNTERSINKING

	Cents per 100 holes							
Diam. of hole, in.	¼	⅜	½	⅝	¾	⅞	1	1⅛
1. In shop	.10	.12	.14	.16	.18	.20	.22	.24
2. On ship	.14	.17	.20	.23	.26	.29	.32	.35
3. Re-ck on ship after reaming	.35	.40	.45	.50	.55	.60	.65	.70

Note—In shop, material to be delivered at machine.

CT — CUTTING, PNEUMATIC

When the cutting is in the body of the metal further from the edges or deeper than ⅜ in., it will be counted as a cutting, the price for which will include payment for all chamfering and filing where such is required. Where work of cutting into metal is intended to remove an amount greater than that required for working the tool, it will be measured by area and average depth of cut. Price and a half to be allowed for all work in tanks and double bottoms when closed in. Intermediate sixteenths will pay the next lower price.

Prices per running ft. per ⅛ in. thickness of metal,

Straight cutting	$.03
Circular cutting, holes 20 in. diam., and greater	.04
Circular cutting, holes 6 in. to 20 in. diam.	.06
Circular cutting, below 6 in. diam.	.08

CF CUTTING OFF, PNEUMATIC

Shapes.

Price per cut based on cross-sectional area of shape cut, that is, weight in lbs. per running foot. For intermediate sizes, use price for larger size in Table.

	Size lb. per running foot							
	Under 8	9	12	15	20	25	30	40
	Price per cut							
1. Straight cutting (work loose on ground or ship)	.05	.07	.09	.11	.14	.17	.21	.28
2. Straight cutting (work in place)	.05	.08	.13	.18	.22	.27	.35	.41
3. Cutting scarphs	.20	.25	.40	.45	.55	.70	.85	1.00

For cutting off by machine, see SHEARING.

CO CUTTING OUT RIVETS

Diameter, inches	½	⅝	¾	⅞	1
Price per 100	1.75	2.50	3.00	3.50	4.00

CX CUTTING, OXY-ACETYLENE PROCESS

Prices, one-tenth of pneumatic cutting prices.

DR DRILLING, PNEUMATIC

All holes drilled into, or through, plates riveted together to be counted as solid metal, no plies to count. Holes in loose plates or in plates only bolted together will be counted for each plate drilled. Overhead work allows price and a half.

	Diameter of holes, inches				
	Prices per hole				
Depth of Drilling—Inches	¼	⅜	½	⅝	¾
⅜	$.010	.011	.012	.014	.016
½	.011	.012	.014	.016	.018
⅝	.012	.014	.016	.018	.020
¾	.014	.016	.018	.020	.022
⅞	.016	.018	.020	.022	.024
1	.018	.020	.022	.024	.026
1⅛	.020	.022	.024	.026	.028

Depth of Drilling—Inches	7/8	1	1 1/8	1 1/4
Up to and Including 3/8	$.018	.020	.022	.024
1/2	.020	.022	.024	.026
5/8	.022	.024	.026	.028
3/4	.024	.026	.028	.030
7/8	.026	.028	.030	.032
1	.028	.030	.032	.035
1 1/8	.030	.032	.035	.038

Note—that for each 1/8 inch increase, either in diam. or depth of holes, add .002 per hole.

DT DRILLING AND TAPPING

Including countersinking and running taps in hole ready for calking.

	Diameter of holes (in inches), up to and including						
	3/8	1/2	5/8	3/4	7/8	1	1 1/4
1. Solid	.030	.035	.045	.06	.08	.10	.15
2. Through	.025	.030	.040	.05	.06	.07	.09

TP TAPPING

Tapping only, prices six-tenths the prices for solid drilling and tapping above.

ER ERECTING

Includes picking up when in reach of Yard crane. Lines attached to plates included in price for plates; securing in place with sufficient bolts. Closed work refers to interior work where the crane cannot drop the plate or angle in the vicinity in which it is to be erected.

Coal Barges.	Shell plates, bottom	$0.75
	Shell plates, side	1.00
	Transverse frames complete	1.50
	Transverse bulkheads complete	2.00
	Deck plates	.075
	Deck doubling plates	.050
	Bulkhead plates	.050
	Bulkhead stiffeners	.010
	Clips	0.05
	Brackets	0.05
	Girder plates, longitudinal	0.75
	Rider plates	0.50
	Angles from 10 ft. down	0.25

	Angles from 10 to 30 ft.	$0.35
	Bounding angles to shell	0.25
General Prices.	Straight work on ship.	
	Plates per sq. ft.	0.01
	Shapes per lineal ft.	0.01

Closed work 50 per cent extra.

LO LAYING OFF

Includes center punching and marking.

Straight price for shapes is for one flange. For two flanges add 50 per cent. Prices are per running ft., for shapes, and per sq. ft., for plates.

	Shapes per ft.	*Plates per sq. ft.*
1. Laying off from templates furnished	$0.01	0.01
2. Making templates	0.01	0.01
3. Making templates and laying off	0.015	0.015

Usual allowance for closed work and overhead work.

Above prices are for all laying off except Universal work where amount of work is at least 1,200 sq. ft. for plates, or 1,000 ft. for shapes.

4. For this work: Laying off from Universal template, plates per sq. ft... 0.05
   Laying off from Universal template, shapes per lin. ft., one flange 0.07

5. Note:—For small plates or shapes in Classes 1, 2, and 3, where number of units from one template is less than 20, allow price and a half. Unit is sq. ft. or lineal ft.

PT PAINTING, PART ONE

Includes all necessary shifting and lowering of stages, but not rigging or unrigging. Smooth surface refers only to recent coat of paint. Scaled and wire-brushed surfaces to be considered rough or first coat.

Item	*Price per sq. ft.*	*Daily task, sq. ft.*
1. First Coat Red Lead	$ .0050	800
Note:—Allowances will be made for overhead work in the form of 1.5 sq. ft. for each sq. ft. of overhead work done.		
2. First Coat Slate Color over red lead. Working from stages	.0038	1,000
3. First Coat Slate Color over red lead. Working from floats	.0027	1,500
Note:—Stages and floats to be set for the painters, to be adjusted by the painters.		

Item	*Price per sq. ft.*	*Daily task, sq. ft.*
4. First Coat White over Red Lead, inside work, plain side	$.0028	1,400
Note:—Allowances will be made as follows:—Side, with rivets, 1 ft. equals 2 ft. plain side. Side, obstructed, 1 ft. equals 2 ft. plain side. Overhead, plain, 1 ft. equals 2 ft. plain side. Overhead, obstructed, 1 ft. equals 3 ft. plain side.		
5. Second Coat White	.0019	2,100
Allowances:—		
1 ft. plain side equals 1 ft.		
1 ft. plain overhead equals 2 ft.		
1 ft. obstructed side equals 2 ft.		
1 ft. obstructed overhead equals 3 ft.		
6. Burning Off Old Paint, plain side	.0100	250 units
Allowances:—		
1 sq. ft. plain overhead equals 2 units.		
1 sq. ft. outside of boat equals 2 units.		
1 sq. ft. inside of boat equals 5 units.		
7. Cork Painting	.0045	900

PT

PAINTING, PART TWO

Ship's Bottom

1. First Coat Norfolk anti-corrosive bottom paint (applied to bare metal)	.0015	2,700
Note:—Above task and price apply both in case of working from stages and working from bottom of dock; stages to be slung for the painters, to be adjusted by the painters.		
2. Second Coat Norfolk anti-corrosive bottom paint (applied over painted surface)	.0014	2,800
Note:—Above task and price apply both in case of working from stages and working from bottom of dock; stages to be slung for the painters, to be adjusted by the painters.		
3. First Coat Red Lead, ship's bottoms, outside, first coat	.0026	1,500
No Allowances.		
Work to be brushed out thoroughly, but not laid off for appearances.		

Class of work determined by conditions:
(a) Accessibility for riveting
(b) Complexity and difficulty determines skill required
(c) Continuity or contiguity of rivets

Class No.	Price per 100, dollars and cents — *Diameter of Rivet*	3/8	1/2	5/8	3/4	7/8	1	1 1/8
	S—Size Number	3	4	5	6	7	8	9
0.	On ground—Riveting with Bull Machine		1.00	1.25	1.50	1.75		
1.	On ground—Easy structural work with air hammer	1.00	1.25	1.50	1.75	2.00		
2.	On ground—Bulkheads—Decks—Floors	1.25	1.50	1.75	2.00	2.25		
3.	On ship—Beam brackets and gussets—Bulkheads—Deck—Deckhouses—Floors—Longitudinals	1.50	1.75	2.00	2.25	2.50	2.90	
4.	Keel—Keelson—Inner bottom—Shell—Hatches and Coamings—Bounding bars—Stringers—Turrets	1.75	2.00	2.25	2.50	2.80	3.20	
5.	Boat cranes—Chutes—Trunks—Doors—Manhole Covers—Guards—Masts—Bulkhead staples—Clips	2.00	2.25	2.50	2.75	3.10	3.60	
6.	Ammunition hoists—Bilge keels—Cofferdam—Chain lockers—Peak tanks	2.25	2.50	2.75	3.00	3.50	4.10	
7.	Boiler saddles—Engine foundations		2.75	3.00	3.40	3.90	4.60	
8.	Stanchions—Miscellaneous foundations—Struts—Rudders		3.00	3.30	3.80	4.40	5.20	
9.	Stem—Stern post		3.25	3.70	4.30	5.00	6.00	7.50

Classes 3 and 4 are flush riveting prices, in new work. Deduct .25 per 100 for snap riveting prices in new work.

Item	*Price per sq. ft.*	*Daily task, sq. ft.*
4. Second Coat Red Lead, ship's bottoms, outside	$.0018	2,200
No Allowances. Work to be brushed out thoroughly, but not laid off for appearance. *Note:*—Norfolk anti-fouling bottom paint-prices same as Norfolk anti-corrosive above—first and second coats respectively.		
5. Bitumastic solution—straight work	.0015	
6. Bitumastic enamel, 1/16 in. thick or over	.0030	
7. Bitumastic cement, ¼ inch	.0020	

Allowances for 5, 6 and 7 for obstructed work, etc., same as for Painting, Part I, items 4 and 5, white paint.

PL

Planing

Material Delivered at Machine

1. Up to and including ⅜ inch thickness—plates and shapes; per ft. ......$.009
2. Above ⅜ inch thickness—plates and shapes; per ft. .... .012
3. Taking all planing as it comes, heavy or light, shapes; per ft. .... .010

PU

Punching

Material Delivered at Machine

	Per 100 holes
1. Small plates or shapes, handled by 2 men	$0.10
2. Large plates or shapes, handled by 4 men, ½ inch and under	0.20
3. Large plates or shapes, handled by 4 men, over ½ inch	0.25

RM

Reaming

Includes reaming all unfair, or small, holes to proper size and fairness. Only such holes as need reaming to be reamed or counted.

Coal Barges and new work

Diameter, inches:	⅝	¾	⅞	1
	Price per 100			
1. Decks, Inner bottom	$.30	.40	.50	
2. Shell (sides) Bulkheads	.35	.45	.55	
3. Frames, Shell (bottom)	.45	.55	.65	1.00
4. Trusses	.60	.70	.80	

Above is for two-ply. For three-ply add .05 per 100 holes.

General Prices. For new work same as for Coal Barges.

Repair Work, reaming price equals one-fifth riveting price.

RV RIVETING, MACHINE, PART II

SCATTERED RIVETS

Number in One Locality Class 3	Price per 100 dollars and cents				
Diameter in inches	½	⅝	¾	⅞	1
70	1.75	2.00	2.25	2.50	2.90
60	1.80	2.05	2.30	2.55	2.95
50	1.90	2.15	2.40	2.65	3.05
40	2.05	2.30	2.55	2.80	4.25
30	2.35	2.60	2.85	3.10	3.50
20	3.00	3.25	3.50	3.75	4.25
10	4.25	4.50	4.75	5.00	6.50
5	5.75	6.00	6.25	6.50	7.00

Interpolate for an intermediate number.

The above prices are for scattered work on ship, Class 3, as decks, bulkheads, floors and longitudinals. For other classes of work, more difficult or easier, add or subtract 25 cents a hundred to above prices per one change in class.

In general, the above prices are set by using the following allowances for *Preparation,* for various classes of riveting work:

Class No.	0	1	2	3	4	5	6	7	8	9
Time allowance (minutes)	8	10	12	14	16	18	20	22	24	26
Cost allowance	.16	.20	.24	.28	.32	.36	.40	.44	.48	.52

The cost of *Preparation* is thus separated from the cost of *Operating* (driving, holding on, etc.), the same as for all other kinds of work.

The term "preparation" includes: 1. Travel from previous job to the new job. 2. Moving tools and equipment from previous job. 3. "Setting up" and removal of tools and equipment.

ODD RIVETS

In case the rivets are so badly "scattered" that there are less than *five* rivets in one locality, they will be considered as "Odd Rivets" and the following prices paid:

Up to and including ⅝ in. .... $6.00 per 100

Above ⅝ in. .... 8.00 per 100

SC

Scaling

Includes removal of all paint, scale and dirt down to a clean metal surface. On bottoms, grass, barnacles, etc., to be removed prior to scaling.

Inside paint ....$0.015 Outside paint ....$0.008 per sq. ft.

These prices allowed only when the following daily task has been equaled or exceeded.

1............Inside work 130 units
2............Outside work 250 units

If the task is not equaled, day's wages for that day will be paid.

3. Scaling Bottom Steel Ship.
Task ....230 sq. ft. per day
Price ....$.009 per sq. ft.

Note.—Stages will be slung for the scalers, to be adjusted by the scalers; no allowances.

Special prices, equivalents, and further particulars as follows:

The unit is one sq. ft. of plain side plating. For each pad-eye, watertight door, etc., units are allowed as per the following tables:

Inside Work	*Units*
Between rivets, overhead work, beams, all obstructed work, each sq. ft. is equivalent to	2
Corrugated steel, each sq. ft. is equivalent to	3
Rivets (not flush) each equivalent to	1/3
Burning off paint, each sq. ft. is equivalent to	4

Outside Work	
Beading, each running ft. is equivalent to	2
Pad-eyes, each equivalent to	3
Davits steps, each equivalent to	7
Davit collars	13
Awning stanchion step, each equivalent to	4
Awning stanchion collar, each equivalent to	8
Water sheds over air ports, each equivalent to	10
Hinge and pad, each equivalent to	2
Eye bolts, each equivalent to	1

Watertight door (side with hinges):—Multiply length over stiffening ring on bulkhead, by width over stiffening ring, then multiply by two. This gives allowance for everything, except hinges and grab rod, and includes scaling the stiffening ring. Grab rod ....1 unit

Stanchions, davits, pipe, all rounds:

Multiply the diameter in inches by the length in feet. The result is the equivalent number of plain side feet.

SH SHEARING

1. Plates ⅜ in. thick and under, and toes of angles, per ft. ....$.009
2. Plates over ⅜ in. thick .... .011
3. Taking all shearing as it comes .... .010

Equivalent: Cutting off shapes, one cut equals 1 ft.

TL TILING

Laying tiling only in unobstructed space, per sq. ft. ....$.12
Laying tiling and cement in unobstructed space, per sq. ft. .... .15
Allowances for obstructions:
One sq. ft. for each lineal ft. or fraction thereof of periphery of obstruction.

WC WOOD CALKING

(Not including paying seams with glue or puttying same. Oakum will be furnished to calkers, already spun.)

Kind of Work	*No. of threads*	*No. of horsing*	*Cents per ft.*	*Daily task ft.*
1. New work—bottom and sides	4	2	.02	200
2. New work—bottom and sides	3	1	.015	267
3. New work, deck	4	2	.015	267
4. New work, deck	3	2	.014	286
5. New work, deck	2	1	.0135	295
6. New work, deck, 2 threads horse down and fill up with 1 thread left ⅛ inch below deck	3	1	.0125	320
7. Old work—Reeve out, putty, horse down and calk 1 thread	1	1	.011	364
8. Old work—Reeve out, glue, horse down and calk 1 thread throughout	1	1	.0133	301
9. Old work—deck; reeve out, horse down, calk 2 threads	2	1	.015	267
10. New work—deck; three threads, one horsing	3	1	.014	286
11. Old work—deck; reeve out, glue, horse down, calk 1 thread only where necessary	1	1	.0125	320

The above piece-work prices have been used on what is known as "straight work"—that is, where the work was continuous for a considerable period of

time. In order to adapt them to "scattered" work, that is, where there is not a large amount of *continuous* work, special allowance has to be made, since the work of *preparation* is as great, or nearly as great, for performing a small number of units as a large number, as we have previously observed. The allowance No. 4 in table that follows covers this feature; these allowances are obtained or estimated from curves prepared from the records and from observation.

Allowances

over straight work prices not otherwise specified above

No.

1. Overhead work, allow extra .... 50 per cent
2. Beveled shapes and rolled or furnaced plates .... 50 " "
3. Closed in compartment or corner work .... 50 " "
4. For "scattered work"—that is when the number of units of work in one location is less than N in table below, allow extra price per unit as indicated:

Total Price for a small number of units (n) is obtained by adding to the straight work price an extra allowance for "Preparation" (which includes shifting location). This allowance (No. 4) to be equal to P below for 1 unit, and to $\left(\frac{N-n}{N}\right)$ times P for n units.

This total price for n units divided by the number of units (n) gives the unit price.

Operation	*Class*	*N*	*P*	*Allowance* 1, 2, 3,	*Unit*
BO		150	.12	1, 2, 3	Bolts
CA		50	.08	1 3	Lin. ft.
CM	1	10	.10	3	Cu. yd.
	2	80	.10	3	Sq. ft.
CH		80	.08	1 3	L. ft.
CC		80	.08	1 3	Rivets
CK	1, 2	500	.08	1 3	Holes
	3	250	.08	1 3	Holes
CT		16	.08	1	L. ft.
CF	1, 2	25	.10	1, 2, 3	Cuts
	3	8	.12	1, 2, 3	Cuts
CO		70	.08	1 3	Rivets
CX		16	.20	2	L. ft.
DR		100	.08	1 3	Holes
DT		30	.08	1 3	Holes
TP		50	.08	1 3	Holes
LO	1, 2, 3	200	.10	1, 2, 3	Sq. or L. ft.

Operation	*Class*	*N*	*P*	*Allowance* 1, 2, 3		*Unit*
PT	1, 2, 7	600	.06	a		Sq. ft.
(1)	3, 4, 5	1,200	.06	a	See Remarks	Sq. ft.
	6	120	.04	a		Sq. ft.
PT	1, 2, 4	1,500	.06	a		Sq. ft.
(2)	3	800	.06	a		Sq. ft.
	5, 6, 7	1,000	.80	a		Sq. ft.
PL		120	.05	a		Lin. ft.
PU		1,000	.08			Holes
RM		500	.08	1 3		Holes
RV		70	.16 to .52	a		Rivets
SC	1	80	.04	a		Sq. ft.
	2, 3	150	.04	a		Sq. ft.
SH		200	.08	–		L. ft.
TL		200	.20	a		Sq. ft.
WC		200	.10	a		Lin. ft.

Remarks: (a) Covered in prices above by the Classifications and Equivalents, and no other allowances 1, 2, or 3 to be given.

Operation includes ALL classes unless noted otherwise in class column.

The only other allowances for special or unusual conditions is for work at a remote distance from previous job.

For travel in excess of 300 yds. allow 2 mins. day pay per 100 yds. extra.

UNSTANDARDIZED WORK

The foregoing piece rates cover most of the operations involved in the shipfitter trade, as well as some operations by painters, riggers, common laborers, and wood calkers. Only a few other trades will be discussed.

ANGLESMITH WORK. The piece-work schedules for anglesmith work are frequently very extensive and in considerable detail, but no satisfactory method of classifying all such work in a simple manner, similarly to riveting, has been worked out, as far as the writer is aware. Prices depend upon the size and shape of the units worked

on, the number of units assigned at one time, the number of bends and corners, and character of operation. Typical sketches should be prepared for each separate or distinct group or class of object, and each group further classified as to: (1) Cross-sectional area or pounds per running foot. (2) Square or beveled shape; straight or curved. (3) Length in feet (for bending, beveling or cold pressing). The weight or bulk of the unit may also affect the cost of handling.

Where there is a large amount of work of the same general type, an average price can sometimes be set for the whole job; for example, for beveling and bending all the main and reverse frames of a battleship—3 cents per lineal foot is a sample price. For bending and welding rings 24″ diameter and under, \$0.75 for 1½″ flange to \$2.75 each for 4″ flange. All piece rates should be based on thorough observations and study, and not set by guesswork.

Examples of piece rates for bending and welding are shown on page 194. "S" equals size of flange on which bending and welding is done, in inches.

Forge Work. The separation of all forge work in a repair shop into elementary operations, and attempting to standardize them, is a big task; and for purposes of ordinary estimating, this hardly seems necessary at present. The simplest element to base estimates upon seems to be weight; grouping or classifying all the forge work into a few simple classes, similar to good foundry practice. This classification cannot be made all at once, but must result from a study of actual records of unit costs—such unit costs to show the object in detail, the weight, and the number of pieces. In order to obtain such records properly and completely, a good planning system and a good cost-keeping system are, of course, essential. This remark applies equally well to the obtaining of any valuable estimating data whatsoever, and is so evident to any student of the subject that it seems unnecessary to state it, except for the unfortunate fact that a great many executives or managers demand and expect from their subordinates accurate estimates for both new and repair work for which the plant has never furnished any reliable estimating data because of this very lack of an adequate planning system and a good cost-keeping system.

JOGGLES

S	Single		Double	
Inches	Sq.	Bev.	Sq.	Bev.
1½	.03	.04	.10	.12
2	.05	.06	.12	.15
2½	.06	.07	.15	.18
3	.07	.08	.18	.20
3½	.08	.09	.20	.22
4	.09	.10	.22	.24
4½	.10	.11	.24	.26
5	.11	.12	.26	.29
6	.12	.14	.29	.32
8	.18	.22	.36	.40

CORNERS

S	Inside		Outside		Joggled	
Inches	Sq.	Bev.	Sq.	Bev.	Sq.	Bev.
1½	.16	.20	.20	.25	.20	.25
2	.18	.23	.25	.30	.23	.28
2½	.22	.30	.30	.35	.35	.42
3	.33	.40	.38	.42	.45	.56
3½	.45	.50	.55	.60	.55	.60
4	.65	.70	.70	.75	.75	.80
4½	.80	.90	.90	.95	.90	.95
5	.90	1.05	.95	1.10	.95	1.10
6	1.00	1.25	1.15	1.30	1.15	1.30
8	1.50	1.75	1.60	1.80	1.80	2.00
6x6 and 7x7x⅝ and ¾ thick	1.50	1.70	1.80	2.00	2.10	2.20

Angle rings, when welded only: one-third of list prices will be paid. These prices are for welding on the small or narrow flange, if welded on the wide flange, take next higher price.

Shops in General. In this connection, the general principles governing the separation of shipyard operations into logical and practical classes are ably discussed by Naval Constructor G. C. Westervelt, U.S.N., in the *U. S. Naval Institute Proceedings,* No. 148, of December, 1913, in an article dealing more particularly with the bearing which detail planning and the classifying of operations into "schedules" has upon the cost of production. The present discussion only attempts to cover briefly the best means of obtaining good estimating data for ordinary purposes. Mr. Westervelt's observations, however, apply with force to both phases of the subject. He says:—

In order that the use of these schedules might be of practical value, they should be in terms of operations readily understood. . . . They should be designed with the ease of recording directly in mind; and this, more than anything else, would force a departure from a strictly theoretical schedule to a schedule which, while still theoretical, would be practical. . . . The following bases for schedules give good practical results:—Shipfitter shop and sheet metal shop, in terms of elementary operations of trade; sail loft, in terms of feet of stitching and number of eyelets, or of elementary operations; joiner shop, in terms of elementary operations of trade, or of related groups; ship smith shop, in terms of weight; paint shop, in terms of square feet, of elementary operations and of weight.

Piping Work. The same general remarks apply to piping work as to furnace work, regarding the lack of a simple method of standardization. There are so many different kinds of piping and fittings, used for such a variety of purposes, that it would seem to be impossible to tabulate or plot cost data for such work in a satisfactory manner. Using the same general principles of classification, however, as outlined for other branches of ship work, considerable useful estimating data can be collected in convenient form. Piping work can be grouped into (1) Purpose or object of piping, which also means "kind" in most cases—for example (a) Water systems, (b) Voice piping, (c) Air piping, (d) Conduit. These can be further subdivided into physical characteristics. Then comes the classifying of a job in any group into (1) Size and weight of pipe, (2) Length, (3) Number of joints,

(4) Number and character of fittings, (5) Location of work—that is, accessibility, (6) Description of operation—as Disconnect, Remove, Lead-line, Bend, Assemble, Solder, Make joint, etc.

Instead of trying to keep a separate card record for each particular operation, all carefully indexed, especially in the case of piping repair work, it will be better at first to go more slowly and be sure that the data collected is worth while, and that it can be plotted to advantage by logical and simple operations. Here, as in most repair work, the number of units of work performed must be considered, as a large part of cost of piping work consists in "getting started." The collection of estimating data for work done in the field or on shipboard will be much more difficult to get than for shop-work. Planning such work in detail, with the operations set down in logical sequence and scheduled, and with care taken to specify the number of units, will be indispensable toward getting any estimating data of value—and incidentally will lead toward increased efficiency of production.

Plumbing work estimates are fully as difficult to make as estimates for piping work proper, and the same general process can be followed in collecting data. Until it is practicable to standardize such work in a measure, it will be found useful as a preliminary guide and in making rough estimates to estimate direct labor as bearing a certain ratio to cost of material for different classes of work. These classes would distinguish between jobs involving removal of old work and those of installing new work.

It is no easy task to determine the best practical bases for classifying cost data for miscellaneous work, where each job or even each operation is different from any previous job or operation; and yet, until some simple and useful classification is used, and cost records properly "digested" and analyzed they will be of very little use to the estimator in estimating on future work.

It has been seen that in either repetition manufacturing work, or in new construction work, we can sometimes classify costs by the total costs of *objects* or parts, specified by the technical name of the object,

article or part. We can also go further and classify costs by operations—independently of the *names* of articles or parts, except so far as needed to define the conditions or character of the operations as regards (1) *Accessibility* of the work, (2) *Difficulty* or complexity of the work, compared to some simple basic or *standard* degree of complexity, defined by an example, (3) *Continuity* of the units comprising the operation, as determined by the number of units (whatever the unit of measure chosen) which can be performed one after the other without stopping or shifting position of men or equipment.

We can go still further, and subdivide or analyze each of these three main groups of condition factors into its elements, somewhat as Mr. Gilbreth describes in his "Motion Study"—a book that each estimator should read diligently. The extent to which it will be profitable to analyze operations will depend somewhat upon the use to which we wish to put our data, and upon the expense involved in making the analyses. For operations which seldom recur, even in general form or character, to say nothing of those which never recur in identical form, extreme refinement will seldom pay.

In repair and jobbing operations the best way I have ever found to decide how far to go in the classification or analysis, is by *plotting* costs on cross-section paper, as above mentioned. This matter will be further taken up later on. The costs can then be analyzed or separated into a few *classes,* with a smooth curve to represent each class. A simple way to look at a class number is to consider it the sum of the three *condition factors* mentioned; and to have only three or four grades or factors for each condition. For example, 0, 1, 2, and 3 for each of the three conditions; the lowest cost class (0) would mean Accessibility 0, Complexity 0, and Continuity 0. Then we get any combination up to Class No. 9—which means the factor 3 for each condition.

We have already applied this method to classifying "riveting" on pages 186-189; it has been done for castings, forgings, and other work where the unit of measure is the *pound;* for templating, painting, and other operations where the unit is the *square foot;* and can be applied to practically all operations, with a little study and ingenuity.

EXTRACTS FROM "ESTIMATING THE COST OF SHIPS"*

PIECE RATES FOR RIVETING, CHIPPING, CALKING, DRILLING, REAMING, COUNTERSINKING AND LINERMEN

(Fixed by Shipbuilding Labor Adjustment Board for Shipyards of Delaware River and Baltimore Districts. February 25, 1918. 220-225 Munsey Building, Washington, D.C.)

The piece rates prescribed as part of its award by the shipbuilding labor adjustment board, and printed in the piece rate book for Delaware River and Baltimore shipyards, shall under no circumstances be lowered during the duration of the war. In the name of the People of the United States, we urge employees in shipyards to do their utmost towards winning the war by removing all limitations upon output and hastening in every possible way, each according to his capacity, the production of ships.

DESCRIPTION OF WORK

Description	Rate
Keel, from fore peak bulkhead to after peak bulkhead, including garboard seam (including all rivets through flat keel plates). All sizes	$ 8.75
Keel, fore and aft keel rivets from collision bulkhead, forward and peak bulkhead aft. All sizes	12.50
Rolling keel above and below tank top, and rolling keel angles to plate, including bead bar. All sizes	7.50

		Size of Rivets		
Description		7/8	3/4	5/8
Inside work, Vertical keel, including all angles driven at the same time (rider plate off and floors out)		$5.00	$4.50	$4.00
Vertical keel, including all angles (rider plate on and floors in) $1 over above prices for each size. Keelsons, stringers and brackets above double bottom		5.50	5.00	4.50
Shell, between fore peak and after peak bulkheads, including shell bottom and frames when driven with shell, but exclusive of bilge (understood to include water-tight and oil-tight riveting)	1 in. $4.50	4.00	3.50	3.00
Shell bilge (two seams and frames)	1 in. 7.00	6.00	5.00	4.00
Shell sheer strake (must be 1/8 more in thickness than side shell), less than 1 in. thick		5.00	4.50	4.00
Provided, that when plate is 1 in. or more in thickness all sizes to be $6 per hundred.				
Gunwale bar to shell to be included with sheer strake.				
Shell-waist or bulwarks, including beading .... All sizes $5.				

* *Op. cit.*, pp. 214-229.

Shell, fore peak, "A" plate to water-tight flat and above water-tight flat to shelter deck	1 in.	$6.00	5.00	4.50	4.00
Shell fantail	1 in.	6.50	6.00	5.50	4.00
Shell-boss and to first deck above boss (twin screw boats). All sizes		$6.00			
Shell pump room (oil tankers), $0.75 over straight shell rates for each size of rivets.					
Shell in engine room in way of foundations	1 in.	$6.00	5.50	5.00	4.50
Intercostals, tank top off	1 in.	4.25	4.00	3.75	...

PIECE-RATE PRICES

Description of Work			*Size of Rivets* 5/8	3/4	7/8
Intercostals, engine room	1 in.	$4.75	...	$4.25	$4.50
Floors and brackets to center vertical keel clips $0.50 more than price for intercostal tank top off, water-tight floors, driven in ship, through the floors			...	4.50	5.00
Double bottom, non water-tight floors, driven in ship			...	3.25	3.75
Frame clips to margin plate	1 in.	$6.00	...	4.00	4.50
Belt frames, driven in ship	1 in.	5.00	...	4.00	4.50
Tank top, rider plate, no seams	1 in.	5.25	...	4.25	4.75
Tank top, double seams	1 in.	4.50	...	3.50	4.00
Tank top, single seams	1 in.	4.75	...	3.75	4.25
Tank top, engine and boiler room in way of foundation intercostals	1 in.	$5.25	...	4.25	4.75
Water-tight and oil-tight bulkheads on ship	1 in.	4.25	...	3.25	3.75
Bounding bars, driven with bulkheads and clips, on calking side of bulkhead. Single bounding bars $0.25 over corresponding bulkhead price.					
Double bounding bars $0.50 over corresponding bulkhead price.					
Bounding bars, driven alone, and clips to be settled by agreement.					
The above refers to double seam bulkheads only. Single seam bulkheads are to be $0.25 over the price agreed on for double seam bulkheads.					
Stateroom and partition	1/2 in.	$3.00	3.50	4.00	4.50
Cofferdam from keel to bilge (oil tankers). All sizes		8.00			
Cofferdam, side shell (oil tankers). All sizes		9.00			
Cofferdam, all brackets and intercostals (oil tankers)			5.00	5.50	6.00
Deck beam brackets, 24 in. space			...	4.00	4.50

PIECE-RATE PRICES

Description of Work		*Size of Rivets* 5/8	3/4	7/8
Eighteen in. space $0.50 in addition to above prices.				
Deck beam brackets, aft tank and fore tank; forecastle deck, miscellaneous, $0.50 in addition to above prices.				
First deck above hold, single seams $0.25 in addition to other decks, single seam prices.				
First deck above hold, double seams $0.25 in addition to other decks, double seam prices.				
Other decks, single seams		$3.00	$3.25	$3.75
Other decks, double seams	1 in. $4.00	2.75	3.00	3.50
All decks, single closing-in plates		4.00	4.50	5.00
All clips, staples and bars, on deck, when driven with deck, $0.50 in addition to corresponding deck prices.				
All decks over built-in fresh water and small fuel oil tanks		4.00	4.50	5.00
Gunwale bars, through deck, when driven alone	1 in. 6.00	4.50	5.00	5.50
Hatch coaming plates, including clips and fittings, if ready		6.00	6.50	7.00
Hatch covers on ship, if arranged to permit continuous work		3.75	4.25	4.75
Chain locker, through shell. All sizes	6.00			
Chain locker (interior work). All sizes	7.50			
Deckhouse	1/2 in. 2.50	3.00	3.50	4.00
Deckhouse collars and stapling, when driven alone. All sizes	6.00			
When driven with deckhouse $0.50 in addition to deckhouse prices.				
Deckhouse stringers and tie plates when driven with decks		4.00	4.50	5.00
All tie plates when driven alone. All sizes	5.50			
Deckhouse brackets driven alone	1/2 in. 5.00	5.25	5.50	...
All work in forward and after peak. All sizes	8.00			
Fresh-water tanks in ships, not to include tank-top (interior work in fresh-water tanks)		...	4.50	5.00
Skylights. All sizes	4.00			
Shaft alley		3.75	4.25	4.75
Trunk and ventilators (rings)		5.00	6.00	6.50
Uptakes. All sizes	4.00			
Mast small end (location of small end to be determined by agreement)		...	5.25	5.50
Mast, large end		...	4.50	5.00
Hawse pipes (by agreement)				

DAY RATES

	Rate per Hour
Rivet testers	$0.80
Hand riveters	.70
Pneumatic riveters	.65
Holders-on	.50
Heater boys	.38
Pass boys	.30

NOTES

Bull machine riveting to be increased over old rates in proportion. All ground work to be 25 per cent less than on ship.

Hand riveters to receive forty per cent above machine prices for same rivets.

Piece-work rates, not included in this schedule, may be determined by agreement between the foreman and piece-workers concerned; provided that when rates so fixed by agreement are to continue in operation for more than one week they shall be reported to the Examiner of the district and shall be superseded whenever uniform piece rates for such work shall be fixed by the board.

The pay for piece-work riveting gangs employed at work not covered by this piece-rate schedule, or fixed by agreement, is to be an hourly rate determined by averaging their hourly earnings while engaged at piece-work during the net three preceding days of their employment; provided, that when the calculation of the average piece-work earnings by this rule is impracticable, the rate for such gangs on allowance work shall be $22.75 per day of eight hours.

PIECE RATES FOR CHIPPING AND CALKING

Description of Work	*Piece Rates*
Cutting all Plate Scarphs, on ground, per sq. in.	$0.02
Cutting all Plate Scarphs, on ship, per sq. in.	.03
All angle cuts less than 1½ x 1½ in.	.08
All angle cuts 1½ x 1½ in.	.10
All angle cuts over 1½ x 1½ in. up to 3 x 3 in.	.13
All angle cuts 3 x 3 in. up to 4 x 4 in.	.18
All angle cuts 4 x 4 in. up to 5 x 5 in.	.25
All angle cuts 5 x 5 in. and over	.30
All bevel or offset cuts, price and one-half if 45 degree or over.	
Cutting solid bead bar, per cut	.25
Cutting hollow bead, per cut	.15

Description of Work	*Piece Rates*
Straight cutting per ft. per ⅛ in. thick	$0.05
Cutting that cannot be ripped, per ft. per ⅛ in. thick	.07
Cutting plate from heel of bar to calk heel, per ft. per ⅛ in	.08
Circular and elliptical cutting under 4 in. diam. per ⅛ in.	.12
Circular and elliptical cutting 4 in. and up to 8 in. per ⅛ in.	.10
Circular and elliptical cutting 8 in. and up to 24 in. per ⅛ in.	.07
All notches and small cuts	.10
Cutting bulb from bulb bar, straight cutting prices to prevail.	
Cutting all burned edges per ⅛ in. straight	.03
One and one-half ft. of cutting to be allowed on all laps. All overhead cutting, not including cutting necessary for calking work on shell bottom, to be price and one-half.	
Cutting all water stoppers, per ft.	.01
Cutting out rivets:	
⅜ in.	.025
½ in.	.0325
⅝ in.	.0375
¾ in.	.045
⅞ in.	.05
1 in.	.06
1⅛ in.	.07
1¼ in.	.08
Cutting out conical rivets, each	.08
Chipping and calking all tap rivets, per piece	.07
Chipping and calking rivets	.04
For chipping and calking open end of angle, 4 in. x 4 in. or less, one flange	.07
For chipping and calking closed end of angle, 4 in. x 4 in. or less, 1 flange (defined to mean where next to beam under the deck, against the margin bar)	.10
For chipping and calking open end of angle, 5 in. x 5 in. or 6 in. x 6 in., 1 flange	.10
For chipping and calking closed end of angle, 5 in. x 5 in. or 6 in. x 6 in., 1 flange	.175
Flushing all rivets that do not calk	.02
Chipping all bars and plates under ⅜ in. for calking, per ft.	.0375
Chipping all bars and plates under ⅜ in. between brackets for calking, per ft. per ⅛ in.	.04

Description of Work	*Piece Rates*
"Between brackets" is understood to refer to "spaces of three feet or less between brackets or other similar obstructions."	
Chipping all bars and plates ⅜ in. and over, per ft. ⅛ in.	$0.0125
Chipping all bars or plates ⅜ in. and over between brackets for calking, per ft. per ⅛ in.	.015
Straight calking, per ft.	.02
Calking all unplaned bars, per ft.	.025
All fuller work, per ft.	.05
Bent tool calking, per ft.	.03
Butt calking ⅜ in. and under, per ft.	.04
Butt calking over ⅜ in., per ft.	.035
Heel calking, per ft.	.035
Calking angle butts (price and one-half if packed)	.11
Calking one flange	.055
All calking between brackets, where space is 3 ft. or under, per ft.	.03
Calking all rivets between brackets (not chipped)	.03
Calking all rivets on open work	.025
Calking stem and stern post rivets	.0375
Calking overhead rivets to be $0.01 above regular prices. This to include rivets in both flanges of bounding angles under decks and tank top.	
Calking all plugs up to ⅞ in. diameter	.08
Calking all plugs over ⅞ in. diameter	.15
Calking all parallel liners to be straight prices.	
Calking tapered liners under ⅝ in. at head	.15
Calking tapered liners over 18 in. length, straight prices.	
Calking all scarphs to be considered as liners in price. If shoulder of scarph must be cut away, 1 ft. of cutting to be allowed.	
Calking W.T. Staples, deck and bulkhead, heavy	1.15
Calking overhead, W.T. Staples, heavy, price and one-half. Staples made of ⅜ in. angle or heavier to be considered heavy angle.	
Calking W.T. Staples, deck and bulkhead, light	.75
Excess of 30 in. straight work, in addition to regular price. This does not include rivets	
Calking overhead, W.T. Staples, light, price and one-half.	
Watertight calking plate collars around angles, including lugs	.75
In excess of 30 in. straight work, in addition to regular price. This does not include rivets.	
Watertight calking plate collars around channels, including lugs	1.00

Description of Work	*Piece Rates*
Calking round corners, each	$0.03
Butt packing, per ft.	.08
Straight heel packing, per ft.	.07
Trimming, per ft. per 1/8 in., 3/16 in. or under	.015
Trimming, per ft. 1/8 in., over 3/16 in. to and including 3/8 in.	.03

Trimming over 3/8 in., to be counted as straight cutting.

DAY RATES

	Rate per Hour
Tank testers	$0.80
Hand chippers and calkers	.70
Pneumatic chippers and calkers	.65
Packers	.50

PIECE RATES FOR DRILLING

Drilling, per Hundred Holes

Depth of hole up to and including 3/8 in.

Up to and including:

3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
$1.40	$1.70	$2.10	$2.40	$2.80	$3.10	$3.80	$4.60

For each 1/8 in. increase in depth, add $0.30 per hundred.

Drilling and Tapping, per Hundred Holes, Any Depth

Up to and including:

3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
$5.50	$7.00	$9.80	$12.50	$15.30	$19.50	$23.70	$27.80

Drilling, Tapping and Studding, Including Countersinking, per Hundred Holes, Any Depth

Up to and including:

3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
$7.00	$8.40	$11.10	$14.00	$16.70	$20.90	$25.00	$30.00

Cutter Bar Work, per Hole

	Diameter of Hole 1 1/4 in.
Depth of hole up to and including 3/8 in.	$0.098
For each 1/8 in. increase in thickness or diameter	0.025

Odd Work, per Hundred Holes

All holes up to:	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
	$5.60	$7.00	$8.40	$9.70

Thirteen holes, or taps, or less to constitute odd work. All odd taps to be price and one-half. Scattered work, that is, obstructed work, or work that requires constant shifting, by agreement. All overhead work and work on bottom of shell, bilge, and under counter to be paid for at price and one-half.

Drilling Out Rivets, per Rivet

1/4 in.	3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
$.035	$.035	$.035	$.042	$.049	$.056	$.07	$.084	$.098

Drilling, Tapping and Studding Stern Post, per Hole

1 in.	1 1/8 in.	1 1/4 in.
$0.35	$0.42	$0.46

Drilling Stern Struts and Keel, Stern Post on Ground or on Ship, per Hole

Depth of hole per 1 in:

1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
$.056	$.056	$.056	$.056	$.07	$.084	$.125

All Countersinking of Drilled Holes, per Hole

Up to and including:	3/4 in.	7/8 in.	1 in.	1 1/8 in.
	$0.01	$0.014	$0.018	$0.022

DAY RATE FOR DRILLERS

	Rate per Hour
Drillers	$0.60

PIECE RATES FOR REAMING AND COUNTERSINKING

Merchant Shell Work	*Price per Hundred*
Keel block, 1 in. holes, recountersunk, both sides and reamed	$3.06
All bottom, 1 in. holes, recountersunk, one side and reamed	2.00
All shell, 1 in. holes, recountersunk and reamed, full size	1.93
All shell, 7/8 in. holes, recountersunk and reamed, full size	1.53
All shell, bulkhead bars, 7/8 in. recountersunk and reamed	1.50
All shell, bulkhead bars, 7/8 in. recountersunk and reamed, 2 sides	2.66

All bad holes to be reamed second time, double price for all sizes. All hard jobs by agreement.

Merchant Inside Work	*Price per Hundred*
Deck, ½ in. reamed and recountersunk holes	$0.612
Deck, ⅝ in. reamed and recountersunk holes	.765
Deck, ¾ in. reamed and recountersunk holes	.92
Deck, ⅞ in. reamed and recountersunk holes	1.15
Bulkhead, ½ in. reamed and recountersunk holes, on ship	.765
Bulkhead, ⅝ in. reamed and recountersunk holes, on ship	.85
Bulkhead, ¾ in. reamed and recountersunk holes, on ship	1.15
Bulkhead, ⅞ in. reamed and recountersunk holes, on ship	1.50
Flat machine, reamed and recountersunk holes (all sizes)	3.06
Brackets, ¾ in. reamed and recountersunk holes	1.15
Brackets, ⅞ in. reamed and recountersunk holes	1.50
All lugs, reamed holes	1.50
Bulkhead, ¾ in. reamed and recountersunk, on ground	.85
Bulkhead, ⅞ in. reamed and recountersunk, on ground	1.00
Frame work, ¾ in. reamed and recountersunk, on ground	.612
All punched holes not countersunk and to be countersunk	1.53

All bad holes to be reamed second time, double price for all sizes. All hard jobs by agreement.

Torpedo Boat Shell Work	
All shell, ⅜ in. reamed and recountersunk holes	.60
All shell, ½ in. reamed and recountersunk holes	.85
All shell, ⅝ in. reamed and recountersunk holes	1.15
All shell, ⅝ in. and ¾ in. odd holes	1.53
All shell, ⅝ in. and ¾ in. reamed and new holes	2.00
All shell, bulkhead bars reamed and new holes	3.06

Torpedo Boat Inside Work	
Deck, ⅜ in. reamed and recountersunk holes	.46
Deck, ½ in. reamed and recountersunk holes	.612
Bulkhead bars, ⅜ in. reamed and recountersunk holes, 1 side	1.15
Bulkhead bars, ⅜ in. reamed and recountersunk holes, 2 sides	1.53
Ground work, ½ in. reamed and recountersunk frames, etc.	.765
Ground work, ⅜ in. reamed and recountersunk frames, etc.	.535
Bulkheads, on ground, ⅜ in. reamed and recountersunk holes	.46
Bulkheads, on ground, ½ in. reamed and recountersunk holes	.535
Shell, ⅝ in. reamed and countersunk holes	1.15
Shell, ⅝ in. and ¾ in. new recountersunk holes	1.53

Torpedo Boat Inside Work

Shell, bulkhead bar reamed and recountersunk holes	$3.06
Mast holes, ⅞ in.	1.50
Mast holes, ¾ in.	1.00

DAY RATE FOR REAMERS

	Rate per Hour
Reamers	$0.50

PIECE RATES FOR LINERMEN

Description of Work	*Price per Liner*
Frame liners, tapered, 3½ in. wide	$0.15
Frame liners, 10 in. wide	.20
Shell liners, tapered	.15
Shell liners, bulkhead	.25
Bulkhead liners, tapered	.10
Bulkhead liners, parallel	.12
Deck liners, tapered	.12
Deck liners, parallel	.15
Boiler and engine casing, tapered liners	.10
Boiler and engine casing, parallel liners	.15
Longitudinal liners, tapered	.12
Longitudinal liners, parallel	.15
Innerbottom liners, tapered	.10
Innerbottom liners, parallel	.12
Fairing out liners on shell and molding	.30
Bosom straps and backing angles	.30
Washer liners on shell, per hundred	1.21

DAY RATES FOR LINERMEN

	Rate per Hour
Linermen	$0.54
Helper	.42½

NOTES

Piece rates for work not included in this schedule may be determined by agreement between the foreman and piece workers concerned; provided that when

rates so fixed by agreement are to continue in operation for more than one week, they shall be reported for record to the Examiner of the district and shall be superseded whenever uniform piece rates for such work shall be fixed by the Board.

Piece-work reamers and countersinkers, when on odd or obstructed work not covered by this schedule or priced by agreement, are to be paid at an hourly rate determined by averaging their hourly earnings while engaged at piece work during the three preceding days of their employment.

PIECE-RATE PRICES

The prices given above for piece work follow the rate fixed by the Shipping Board, February 25, 1918, and were revised one year after, or on February 1, 1919. Some of the prices of February 25, 1918, were increased, that is the prices for shell rivets, which averaged about $0.75 per hundred, over the old rate. Other piece rates held about the same, the day rates were also increased.

THE FOLLOWING GIVES THE DAY RATE

	Rate per Hour
Rivet Testers	$0.86
Riveters	.80
Holder-ons	.60
Heater-boys	.50
Pass-boys	.36
Tank-testers	.86
Chippers and Calkers, hand and pneumatic	.80
Packers	.58
Drillers	.68
Reamers	.58
Driller and reamer Helpers	.54
Loftsmen	.90
Shipfitters	.80
Shipcarpenters	.80
Shipjoiners	.80

This rate of $0.80 per hour applied to all the various trades employed at shipbuilding, except in some few cases such as Leading Men and Special Mechanics, etc. Their rate was $0.86 and $0.90 per hour.

These piece rates that were fixed by the Shipping Board during the war shipbuilding rush, could not be followed in normal times in ship construction, as some of these prices are too high and some too low, although for the class of

work that was assembled in the shipyards in this country during the war period the prices were very close.

On the following pages I have tabulated some piece-work prices that were in use in some of the highest paid shipyards in this country before the war, or along in 1915 and 1916. These prices in some cases are also high, but taking a general average of the work they were intended for, will also be found to be very close. These prices are based on an average day rate of $0.50 for mechanics and $0.30 for helpers, per hour.

It would be a very difficult job to regulate piece-work prices to suit all the different ship yards, as some yards have a much better method of doing work than others, then the different type of vessels must be be considered, also the climate makes quite a difference, especially in the riveting, calking, drilling, etc.

PIECE-RATE PRICES

In the North Atlantic and Great Lakes in the winter months there is a great loss of time and money caused by cold weather, especially in doing work with pneumatic tools, the air hose freeze solid and prevents the compressed air from passing through to the tool, this necessitates thawing the hose which requires time and also adds to the wear and tear of the hose.

In the South Atlantic and Pacific Coast States the climate is much more favorable for shipbuilding, as it is seldom cold enough to freeze the pneumatic tools. There is no ice or snow to contend with in these climates which is a great factor in doing out-door work. The difference in the cost in doing outdoor work in these climates with competent management will average at least 15% less than in cold climates.

PIECE-WORK RATES IN SOME AMERICAN SHIPYARDS BEFORE THE WORLD WAR

Piece Rates for Laying Out Angles and Plates	*Price per Foot*
Lifting the template from the ship, laying out center, punching all holes, one flange lifted, the other flange sketched, under 4 inches	$0.03
Both flanges lifted	.035
Over 4 in., and up to 6 in., one flange lifted, the other flange sketched, both flanges double riveted	.045
Both flanges lifted	.05

These prices include lifting bevels. If the bar has shape $0.01 addition to these prices.

All angles, such as stringer, fender, bulkhead stiffeners, etc., to be $0.01 less than these prices.

Piece Rates for Laying Out Angles and Plates	*Price per Foot*

When templates are furnished from mold loft, the price to be one-half less when lifted from the ship.

Staples under deck between beams, including making templates, and furnishing it to the angle smith, checking work in smith shop when completed, laying out center, punching and bolting them in place on ship, ready to ream.

$2\frac{1}{2}$ x $2\frac{1}{2}$	3 x 3	$3\frac{1}{2}$ x $3\frac{1}{8}$
$0.75	$0.90	$1.00

Staples to bulkheads at margin plate, including peak bulkheads.

3 x 3	$3\frac{1}{2}$ x $3\frac{1}{2}$	4 x 4	5 x 5
$1.00	$1.15	$1.25	$1.50

Corner of bounding angles on bulkheads under and above decks to be one-half price of staples, when under four feet in length, when over four feet to be $.08 per ft. addition for all sizes. Staples that are over 50 lbs. to be placed by the erecting gang.

Angle clips, 3 in. to 4 in. and up to 30 in. long, per ft.	$0.05
When marked from template, furnished from mold loft	.03
Shell liners, marked from template, furnished from mold loft and placed with one bolt, per liner	.08
Lifted from ship and placed with one bolt, per liner	.12
Shell liners to include both tapered and parallel.	
Frame liners marked from template, furnished from mold loft, per ft.	.02

PIECE-RATE PRICES

Frame liners lifted from ship, per ft.	$0.03
This price only includes marking and center punching.	
Deck and bulkhead tapered liners marked from template, furnished from mold loft, per liner	.08
This price includes placing the liner with one bolt.	
Deck and bulkhead, tapered liners lifted from the ship and placed	.12
Beam liners in decks, and also liners in stiffeners on bulkheads to be same price as shell liners in frames.	
Shell plates marked from template, furnished from mold loft per square ft.	.01
Deck plates marked from mold loft template, per square ft.	.008
Bulkhead plates marked from mold loft template	.007
Boiler and engine casings and deckhouse plates marked from mold loft templates	.006

	Price per Foot
When lifted from the ship one-half price addition to these prices.	
Intercostal plates marked from mold loft templates, per sq. ft.	.02
Shaft tunnel plates to be same price as bulkhead plates.	
Boss plates, tuck plates, furnaced keel plates, foundation plates, and all difficult plates to mark, to be determined by agreement.	
Frames marked from mold loft template, upper leg, per ft.	.015
This includes channels and angles.	
Frame on floor plate, including reverse angle or top bar, per ft.	.01
Floor plates, including watertight floors, per square ft.	.005
Deck beams to be same price as upper leg of frames.	
Beam brackets $0.03 per square ft., size of bracket to be figured as square. Other brackets $0.05 per square ft.	

PIECE RATES FOR PUNCHING

	Weight per Square Foot	*Price per 100 Holes*
Plates under 18 feet long	40 lbs.	$0.50
	35 "	.45
	30 "	.40
	25 "	.35
	20 "	.30
	17½ "	.30
	15 "	.25
	12½ "	.25
	10 "	.20
	7½ "	.20

When plates are over 18 feet long, or over 5 feet wide, to be $0.05 per hundred additional.

	Size of Angles	
Angles under 30 feet long	2 x 2	.12
	2½ x 2½	.14
	3 x 3	.16
	3½ x 3½	.18
	4 x 4	.21
	5 x 5	.25
	6 x 6	.30

When bars are over 30 feet long, $0.05 per hundred additional.

PIECE-RATE PRICES

	Size of Channel	Price per 100 Holes
Channels under 30 feet long	6 in.	$0.30
	7 "	.33
	8 "	.36
	9 "	.38
	10 "	.40
	12 "	.45

When bars are over 30 feet long, $0.08 per hundred additional.

All angles and channels that are beveled, or that have curvature, including angle smith work, also deck beams with camber, $0.10 per hundred additional.

COUNTERSINKING IN SHOP

	Diameter of Holes	Price per 100 Holes
Material to be placed on a table, or in a convenient place, so one man can handle it	½ in.	$0.15
	⅝ "	.18
	¾ "	.21
	⅞ "	.25
	1 "	.30
	1⅛ "	.35
	1¼ "	.40

PLANING MATERIAL DELIVERED AT PLANER

	Price per Foot
¼ to ½ in plate, above 12 feet long, per lineal foot	$0.01
⅝ to 1 in. plate	.015
Plates under 12 feet long, and plates with curvature	.2

These prices also include angles from 2 x 2 to 6 in.

PIECE RATES FOR FURNACING ANGLES

	Price per Foot
2 x 2 in. and 2½ x 2½ angle, bending and setting to shape	$0.05
3 x 3 in. and 3½ x 3½ angle, bending and setting to shape	.06

	Price per Foot
4 x 3 in. and 4 x 4 angle, bending and setting to shape	.08
5 x 5 in. angle, bending and setting to shape	.09
6 x 6 in. angle, bending and setting to shape	.10

For beveling $0.03 per foot additional to these prices.

5 x 3½ in. and 6 x 3½ in. to be same price as 6 x 6 in. angle.

PIECE RATES FOR FURNACING CHANNELS

	Price per Foot
6 x 3½ channel, bending and setting to shape	$0.10
7 x 3½ channel, bending and setting to shape	.11
8 x 3½ channel, bending and setting to shape	.12
9 x 3½ channel, bending and setting to shape	.13
10 x 3½ channel, bending and setting to shape	.14
12 x 3½ channel, bending and setting to shape	.16

These prices to include channels with flanges from 3 in. to 4 in. For beveling $0.03 per foot additional to these prices.

The boss and cant frames to be same price as ordinary frames, except shaping the boss and knuckling of cants to be done by angle smith.

PIECE-RATE PRICES

For beveling gunwale angles, stringer angles, or any angles that have little curvature, the price will be the same as for beveling frames. Angles with curvature such as angles around the stern or bluff bow, the price to be the same as for bending and beveling frames. Bulb angles to be considered as channels in price.

Number of men at the furnace to include frame bender and four helpers. Frame bender to get 32 per cent and the helpers 17 per cent. The man at the winch and the man who tends the furnace is furnished by the company.

ERECTING PLATES AND SHAPES

Angles 3 x 3 in. and up to 6 x 6 in., open work, per foot	$0.01
Closed work, such as between decks and in hold, per foot	.015
Beams, including angles, channels and bulb angles 6 x 6 in. and up	.01
Frames above tank, angles or channels 6 x 6 in. and up, per foot	.015
Floors, including watertight floors, with angles bolted or riveted to same, this to include all floors, per plate	.50
Deck plates, 20 ft. and under, open work, per plate	.60

Over 20 feet, $0.05 per linear foot additional.

Closed work, such as between decks, and places where the crane cannot reach, one-half price additional to open work.

Tank top plates to be same price as deck plates.

Shell plates on the bottom in the square body from keel to bilge	.60
Shell plates on side where crane can reach	1.00
Where extra rigging has to be used, such as bow and stern	1.50
Bulkhead plates, on the ship, per plate	.60
Bulkhead plates, on the ground, per plate	.40
Stiffener angles, on the ship, per foot	.01
Stiffener angles, on the ground, per foot	.006

All work must be secured with sufficient bolts to insure safety.

PIECE RATES FOR RIVETING FOR MERCHANT SHIPS AND OIL TANKERS

Description of Work	¾ in.	⅞ in.	1 in.
Keel from fore peak bulkhead to after peak bulkhead	$5.50	$6.00	$6.50
This price to include all rivets through flat keel plate.			
Bar keel, including finishing the head	10.00	12.00	14.00
Shell between fore peak bulkhead, to after peak bulkhead, and from keel to turn of bilge	3.50	4.00	4.50
Bilge from bottom to side, or the curvature of bilge	4.00	4.50	5.00
Shell side, from bilge to sheer strake, and between fore peak and after peak bulkheads	3.00	3.50	4.00
Sheer strake to be the same price as bilge	4.00	4.50	5.00
Fore peak, shell from stem to peak bulkhead	3.50	4.00	4.50
After peak, shell from peak bulkhead to over-all length	4.00	4.50	5.00
These prices include boss and tuck plates.			
Stem, including connection to keel plate	15.00	18.00	20.00
Stern post, including all rivets through post	18.00	20.00	22.00
These prices for stem and stern post rivets include finishing the heads of the rivets.			

PIECE-RATE PRICES

Description of Work	*Cost per 100* ¾ in.	⅞ in.	1 in.
Vertical keel, bottom angles countersunk	$3.50	$4.00	$4.50
Top vertical keel bar countersunk	3.00	3.50	4.00
Vertical keel clips countersunk	3.00	3.50	4.00

If not countersunk, these prices to be $0.50 less.

Description of Work	Cost per 100 ¾ in.	⅞ in.	1 in.
Intercostal, including top and bottom angles	2.50	3.00	3.50
In engine space $0.50 more than ordinary spaces.			
Ordinary plate floors, riveted by bull riveter	1.25	1.35	1.50
Watertight floors $0.25 more than ordinary floors.			
Margin plate angles, including clips and butts	3.50	4.00	4.50
Tank top plating in cargo space	2.50	3.00	3.50
Tank top in engine and boiler spaces $0.50 additional	3.00	3.50	4.00
Bounding angles and clips, riveted through tank top	3.00	3.50	4.00
Foundation angles and clips through tank top	3.25	3.75	4.25
Bulkheads to lower deck, or to first deck	2.50	3.00	3.50
Bounding angles through bulkhead, including bracket angles	3.00	3.25	3.75
Bulkheads above lower deck	2.25	2.75	3.25
Single seam bulkheads to be $0.25 per hundred over price of double riveted seam bulkheads.			
Shaft tunnel to be same price as bulkheads below deck.			
Beam brackets and brackets to stiffeners on bulkheads below first deck above tank top	2.25	2.50	2.75
All brackets and foundations in engine and boiler spaces	2.75	3.00	3.25
First deck above tank top, that is a continuous deck	2.50	3.00	3.50
Decks above first deck	2.25	2.75	3.25
Bounding angle, including stringer angles and clips	2.50	3.00	3.50
Gunwale bar through deck	3.00	3.50	4.00
Boiler and engine casings and deckhouses snap riveted	2.25	2.50	...
Boiler and engine casings and deckhouses flush riveted	2.50	2.75	...
All beam brackets and brackets to bulkheads above first deck, including bulwark braces	2.25	2.50	...
All ⅝ and ½ in. rivets to be $0.25 per hundred less			

PIECE RATES FOR CHIPPING AND CALKING

	Cost per Foot
Chipping plates and bars for calking ¼ and ⅜ in. thick	$0.03
Two cents per ⅛ in., addition for each ⅛ in. increase.	
Chipping plates and bars in close places, such as between brackets and frames, one cent addition to straight chipping.	
Straight calking, per foot ¼ to ¾ in. thick, plates or bars	.015
Butt calking ⅜ and under	.04
Over ⅜ in. thick	.03

	Cost per Foot
Calking the heel of angles	.025
All calking between brackets, including clips	.03
Chipping and calking countersunk head rivets, ⅝, ¾, ⅞, in.	.03
1 in. 1⅛ in. and 1¼ in., including rivets in stem and stern frame	.04
Chipping and calking rivets in overhead work, this to include rivets in both flanges of bounding angles under decks and tank top	.05
Calking all parallel liners to be same price as straight calking, tapered liners one cent per foot extra.	

PIECE-RATE PRICES

	Cost per Foot
Calking scarphs, same price as tapered liners.	
Calking staples and collars	$0.03
Calking all bounding angles for foundations in engine and boiler spaces, also shaft tunnel bounding angles and clips	.03
Straight cutting, per foot, per ⅛ in. thick	.05
Cutting that cannot be ripped, per foot per ⅛ in. thick	.06
Circular cutting, under 4 in. in diameter, per ⅛ in. thick	.08
Cutting all plate scarphs on ground, per square inch	.02
Cutting all plate scarphs on ship, per square inch	.025
Cutting the bulb from bulb bar and chipping it fair	.30
Cutting all angles and channels, $0.008 per in., per ⅛ thick.	
Cutting solid bead bars, per in. per width of bar	.05
Cutting hollow bead bars, per in. per width of bar	.04
Cutting heads of rivets, including backing out the rivet, ½ in.	.04
Add one cent per rivet for each size of rivet.	
Cutting the countersink and backing out the rivet, ½ in.	.05
Add one cent per rivet for each size of rivet.	

All overhead work to be price and one-half addition to straight work.

The price for calking will include payment for all chipping necessary to fair the edges and to make good calking. Assuming the average amount chipped from the edge of any metal to be less than ¼ in. Where a greater amount is removed it will be paid for according to the regular cutting schedule. Calking corners of staples or bounding angles, with or without dutchmen, included in straight prices for calking. Joggles over laps or plate butt straps, etc., included in straight calking. Filling pieces to be allowed extra only where required throughout length of open butt. Price and one-half to be allowed all work in tanks and double bottom when closed in.

PIECE RATES FOR DRILLING

Price per 100 Holes

3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
$1.25	$1.50	$1.75	$2.25	$2.75	$3.25	$4.00	$5.00

The depth of hole to be not less than 1/2 in. or not more than diameter of rivet, when more than diameter of rivet, add $0.25 per hundred additional.

DRILLING AND TAPPING

Price per 100 Holes

3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
$4.50	$5.50	$6.00	$6.50	$8.00	$10.00	$13.00	$16.00

PIECE-RATE PRICES

Countersinking and Screwing in the Bolt, including Finishing the Bolt.

3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
$4.00	$4.50	$5.25	$6.00	$6.75	$7.50	$8.25	$9.50

Drill Out Countersunk Rivets per Hundred

1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.
$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00

These prices are intended for straight work, all odd and obstructed work to be per agreement.

Reaming Holes per 100

Shell, 3/4, 7/8, and 1 in. holes, including recountersinking unfair holes	$0.40
Tank top, 3/4, 7/8, and 1 in. holes, including recountersinking	.35
Decks, 5/8, 3/4, 7/8 in., including recountersinking	.30
All bulkheads below first deck, 5/8, 3/4, 7/8 in. holes	.35
All bulkheads above first deck, 5/8, 3/4, 7/8 in. holes	.30
Bounding angles where double, 5/8, 3/4, 7/8 in. holes	.40
All bulkheads reamed on ground, 5/8, 3/4, 7/8 in. holes	.25
All clips to brackets, intercostals and foundations	.50
All floors and frames on ground	.30
Shaft tunnel, including all holes	.35
Beam brackets below first deck	.50
Beam brackets above first deck	.35
Boiler and engine casings and deckhouses	.25

These prices are based on reasonable fair holes, and all holes to be counted, the reamer to run through all holes. Where holes are very unfair the price to be determined by agreement.

BOLTING UP

Taking the plate after being adjusted and bolting tight ready for reaming. These prices include all classes of work.

	Weight of Plates	*Plates not Rolled or Furnaced*	*Plates Rolled or Furnaced*
Price per bolt	40 lbs.	$0.04	$0.05
	35 "	.035	.045
	30 "	.035	.045
	25 "	.03	.04
	20 "	.025	.03
	17½ "	.02	.025
	15 "	.02	.025
	12½ "	.015	.02
	10 "	.015	.02

G. Reference Works

Cost Keeping and Business Organization

Cost of Manufactures and the Administration of Workshops.
Capt. Henry Metcalfe, Ordnance Dept., U. S. A. John Wiley & Sons, New York, 1885.

Management of Engineering Workshops.
Arthur H. Barker, Technical Publishing Co., Manchester, 1899.

Factory Manager and Accountant.
Horace Lucian Arnold. Engineering Magazine Co., 1903.

Principles of Industrial Organization.
Dexter S. Kimball. McGraw-Hill Book Co., 1913.

Factory Organization and Administration.
Hugo Diemer. McGraw-Hill Book Co., 1910.

Proper Distribution of Expense Burden.
A. Hamilton Church. Engineering Magazine Co., 1908.

Works Management.
W. D. Ennis. McGraw-Hill Book Co., 1911.

APPLIED METHODS OF SUCCESSFUL MANAGEMENT

Shop Management.
Fred W. Taylor. Transactions American Society of Mechanical Engineers, June, 1903.

Work, Wages and Profit.
H. L. Gantt. Engineering Magazine Co., 1911.

Efficiency as a Basis for Operation and Wages.
Harrington Emerson. Engineering Magazine Co., 1909.

Methods of the Sante Fe.
C. B. Going. Engineering Magazine Co., 1909.

Applied Methods of Scientific Management.
Frederic A. Parkhurst. John Wiley & Sons, 1912.

Motion Study.
Frank B. Gilbreth. D. Van Nostrand Co., 1911.

Ford Methods and the Ford Shops.
Horace L. Arnold. Engineering Magazine, 1914.

ANALYSIS OF COST RECORDS

Cost Reports for Executives.
Benj. A. Franklin. Engineering Magazine Co., 1913.

For further reference works, the reader is referred to the bibliography in "Factory Organization and Administration," by Hugo Diemer. Professor Diemer gives a brief outline of the subject-matter of various reference works.

In the attempt to keep the present volume *brief*, for convenience of reference, the writer realizes that the treatment of many important propositions discussed by the various able managers and writers has been very incomplete. In fact, in some cases, it has been impossible to convey the main meaning of the authors in this kind of treatment; and the reader is requested to study the books referred to at some length, for a clearer understanding of their application to the subject of estimating and cost keeping.

A few brief quotations from some of the above reference works will be given, in the hope of emphasizing certain features of the discussion by the weight of well-known authorities of wide experience and unusual powers of accurate thinking and expression, and in the hope of further persuading the reader of the profit to be gained by more extensive study.

QUOTATIONS FROM AUTHORITIES

"There is no question that the cost of production is lowered by separating the work of planning and the brain work as much as possible from the manual labor. When this is done, however, it is evident that the brain workers must be given sufficient work to keep them fully busy all the time. They must not be allowed to stand around for a considerable part of their time waiting for their particular kind of work to come along, as is so frequently the case.

"The belief is almost universal among manufacturers that for economy the number of brain workers (or non-producers, as they are called) should be as small as possible in proportion to the number of producers (i.e., those who actually work with their hands). An examination of the most successful establishments will, however, show that the reverse is true."—TAYLOR.

* * *

"Of all the farces in management the greatest is that of an establishment organized along well-planned lines, with all of the elements needed for success, and yet which fails to get either output or economy. There must be some man or men present in the organization who will not mistake the form for the essence, and who will have brains enough to find out those of their employees who "get there," and nerve enough to make it unpleasant for those who fail, as well as to reward those who succeed. No system can do away with the need of real men. Both system and good men are needed, and after introducing the best system, success will be in proportion to the ability, consistency and respected authority of the management."—TAYLOR.

* * *

"Two fundamental principles of cheap production lie hidden away amongst inefficient shop processes, bewildering disorder of shop conditions, and lax, inaccurate and utterly misleading shop methods. They are of the greatest importance and yet nine times out of ten a searching investigation will prove that little consideration has been given them in ordinary shop practice. They are so closely related that their simultaneous discussion is advisable. They are both essentially 'time savers.' These two principles are:

"(1) The determination of 'standard time' for each job and its tabulation, introduction and enforcement.

"(2) The absolute elimination from the workman's routine of every duty but that of running his machine continuously and efficiently; the bringing to him of tools and stock for his next job before he is ready for it."—CARPENTER.

* * *

"No record can, as a rule, be kept of men doing miscellaneous work unless it is properly planned ahead of time with that object in view. If it is intelligently planned and an increased compensation given for increased efficiency, an improvement will result which will far more than pay for the expense of planning and record-keeping."—GANTT.

* * *

"If the operation is but seldom done, it may not pay to spend much time training workmen to do it with great efficiency. In this case we should not make the task too severe, but such as a good workman can do without the preparation of special training.

"This studying of the elements of a piece of work and setting proper tasks or piece rates, though an important part of any proper system of management, is only a part. The broad problem which includes all others is to develop a system that encourages the study of all operations and adequately rewards all that co-operation (*sic*) for their continued, efficient performance."—GANTT.

* * *

"When a simple system of stating all costs—whether for a single task for man or machine, or for all a man's work for any period, or for all the work of a gang or department, or for a whole plant, is available; when this system permits parallel statement of actual and standard costs—then the whole problem is well-nigh solved, patience, persistence, fidelity, and high ideals accomplishing the results, through the use of staff specialists."—EMERSON.

* * *

"There is, however, a growing interest in the recording of basic data and its systematic use in all lines of industrial work. The possibility of successfully planning industrial work rests directly upon the possession of such data. The extent *to which it will pay* to plan work in advance will be governed by the regulative principle of the relation between unit cost and volume of product."—KIMBALL.

* * *

"In its dealing with the internal affairs of the business, the cost system, to be right and practical, must not merely present fairly true and proved costs of all articles produced (which has long been considered the chief if not indeed the only use of a cost system), but it must present constantly and comparatively pictures of the progress of certain sections of the business, showings of the divisions and departments, wastes, variations from the standard of costs of operations of labor and expense. It must, beginning at general or specific totals, be prepared to run back over the ground and show fact and reason, in slightest detail, of differences observed by comparison, or of operations desired for whatsoever reason."—FRANKLIN.

* * *

"The question of estimating is a big one, and the writer does not intend here to go into the problems concerned with the manner of making estimates. There are many who believe that it is practically impossible to make any great improvement in the accuracy with which the probable cost of naval repair work can be foretold, placing their opinions on the ground that no two jobs are sufficiently alike to warrant the expectation that past performances can be duplicated in future work. They also point to the fact that it is the unexpected element which so frequently renders final cost disproportionate to the estimate, as, for example, when a boiler, whose condition must be judged from the outside only, is opened up for repairs and found to be in a much worse state than was anticipated.

"The writer believes that a close study of this subject will prove that while practically all repairs differ when considered in toto, yet there is some uniformity in the various operations which go to make up various classes of completed work, and that these operations can be, to a certain extent, *classified.* Estimates based upon a series of operations, each of which has a probable cost fixed by experience, should then be more accurate than merely considering the proposed job as a whole."—Paymaster CHARLES CONRAD, U.S.N., *Proceedings of Naval Institute,* Vol. 137, March, 1911.

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Extract from *The Iron Age,* November 5, 1914. "Manufacturing with a Planning Department," by GEORGE DE A. BABCOCK:

"An equation for cost is given which represents Cost as composed

of the cost of planning plus the cost of operating plus all other expenses chargeable to the order.

"Then follows: Since the labor cost of any work is the rate paid labor times the time taken, the combination of these two fundamentals must be carefully considered in estimating from an analysis. The second factor, time, is so usually the unknown and therefore such an uncertain one that managers are inclined to distribute their classes of work on the basis of rate only. This is unsound.

"The world lacks woefully information as to unit times for standard efforts. Tremendous inefficiencies exist due to the fact that one manager after another must go to extraordinary costs in securing the same information. This does not in any sense entirely enrich our industrial world, either through capital or labor."

Two good books published by McGraw-Hill Book Co., New York, N.Y., in 1940, are:

"Business Methods in the Building Field," by George Schobinger and Alexander Lackey.

"Construction Estimates and Costs," by Professor H. E. Pulver, University of Wisconsin.

In the first book mentioned, several of the twelve chapters apply to shipbuilding or any sort of building work. Chapter IX is especially valuable, entitled *The Estimate,* and the sub-headings are well-worded (pages 175 to 187) as follows:

(a) The function of the estimate
(b) Various purposes served
(c) Difference in method of preparation and presentation
(d) Adaptation to control system of cost accounting
(e) The budget estimate
(f) Adapting the development of project to budget
(g) Contingency item
(h) Builder's contingency provides for unpredictable events
(i) Owner's contingency a distinct item
(j) Changes
(k) How compensate the builder for changes
(l) Revised estimate
(m) Final estimate

We quote a few paragraphs only from Schobinger and Lackey, page 175:

"Since the first appearance of Gillette's *Handbook* on cost data, almost 40 years ago, innumerable volumes have been written on construction costs and their analysis and synthesis. In this volume, the principal purpose of which is to inquire into methods and procedures for the purpose of leading the engineer toward the conservation of his time, the treatment of the subject of the estimate is limited to the same purpose and consequently avoids discussion of the minutiae of estimating individual construction costs.

There are six phases of the estimating function, each signalized by a document serving a specific purpose:

1. The Preliminary Estimate, to determine the economic feasibility of the project.

2. The Engineers' Detail Estimate, to form the basis for the owner's budget, establish the physical content of the project as to scope, type of construction, character of material and general quality, and control the cost.

3. The contract Estimate, to establish the amount of the consideration as an essential element of the general construction contract.

4. The estimates of change in Scope (Extras to the Contract) to establish the contract consideration corresponding to changes in the amount of work required of the builder under his contract.

5. The Monthly (or Periodic) Revised Estimates, to establish for the owner, currently, the total amount of his contractual commitment, so far as it can be established at the time.

6. The Final Estimate, or statement of the cost of the complete work.

The content and the method of preparation of each of these estimates differ from all the others."

Quotation from Kendrick Lee on the subject of "Incentive Wage Payments," page 318, Editorial Research Reports, Vol. I, No. 18:

"A major reason for the disrepute of incentive systems among workers is the tendency of manufacturers to cut rates after they have once been established. All too often employees find that after they have increased their production in order to obtain the higher earnings, manufacturers arbitrarily decide that the workers are making extra money primarily because the original rate was set too high. After the rate has been cut, the workers discover that they have increased their effort and output, but have failed to achieve any substantial increase in earnings."

There are several more good and modern books that might be given as reference works but those chosen cover most of the essentials of the main theme of this present book.

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